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Contract NAS 9-12646

FINAL REPORT OF APPLICATION OF REMOTE
SENSING CONTRACT FOR YEAR ENDING
JANUARY 10, 1973

Compiled and Edited by

W. J. Graff - Professor and
Principal Investigator

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January 10, 1973

DEPARTMENT OF CIVIL ENGINEERING
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158

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Prepared for the National Aeronautics and Space Administration
in fulfillment of Contract NAS-9-12646 by members of the Civil
Engineering Department, University of Houston, Houston, Texas 77004

I

FOREWORD

This is the final report of Contract NAS-9-12646 "Application of Remote Sensing" for the year ending January 10, 1973. The objective of this first year of the contract has been to demonstrate the procedures for using remotely sensed earth observation data -- that is, small scale color and color infrared photography -- to locate potentially suitable sites for sanitary landfills within selected regions of the Houston Area Test Site (HATS).

Besides this detailed final report, the U. H. project team issued three technical reports. The first was "Factors Concerned With Sanitary Landfill Site Selection: General Discussion", dated August 31, 1972. Next was "Regulatory Standards and Natural Characteristics Applicable to HATS", dated September 30, 1972. The third was "The Economic and Social Aspects of Sanitary Landfill Site Selection", dated October 31, 1972.

The U. H. team, enumerated on the title page, is most grateful for the generous help it received from individuals and organizations contacted over the past year. There are too many persons to permit acknowledging each one here. We are appreciative of the help received from the county and city administrations of the five counties, Harris, Brazoria, Fort Bend, Liberty, and Montgomery; and also these organizations: U.S. Soil Conservation Service, Area and District offices; U.S. Geological Survey, Houston office; U.S. Army Corps of Engineers, Galveston District; Port of Houston Authority; Texas State Department of Health; Texas Water Quality Board; and the Houston-Galveston Area Council.

Although this is a report on past work, Chapter VI at the end of the document outlines briefly plans for the next year.

January 10, 1973

W. J. Graff

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INTRODUCTION

This is the final report of Contract NAS 9-12646 for the period of January 10, 1972 to January 10, 1973. The contract with the Manned Spacecraft Center of the National Aeronautical and Space Administration is entitled "Application of Remote Sensing". This year was the first year of the contract and the application effort was devoted to demonstrating the usefulness of small scale aerial color photography and color infrared (IR) photography for locating potentially suitable sites for sanitary landfills.

Three interim reports were completed as part of the preliminary effort for this period (see FOREWORD). While one of the interim reports discussed in general terms the social and economic aspects relating to proper location of potential sanitary landfill sites, it was decided early in the period not to try to evaluate these aspects in the case studies of several selected counties within the Houston Area Test Site (HATS), see Figure 1. The intangible nature of social acceptance and economic soundness of an endeavor depend on human interactions and public relations and are not factors discernible or inferable from color photography or color IR photography.

This report presents in the first chapter a cursory discussion of remote sensing and aerial photographic interpretation, subjects about which several recent and exhaustive treatments have been published. Chapter II summarizes the specific imagery used in this investigation. These data were supplemented with published data from several sources and with many contacts, both personal and by letter, with quasi-

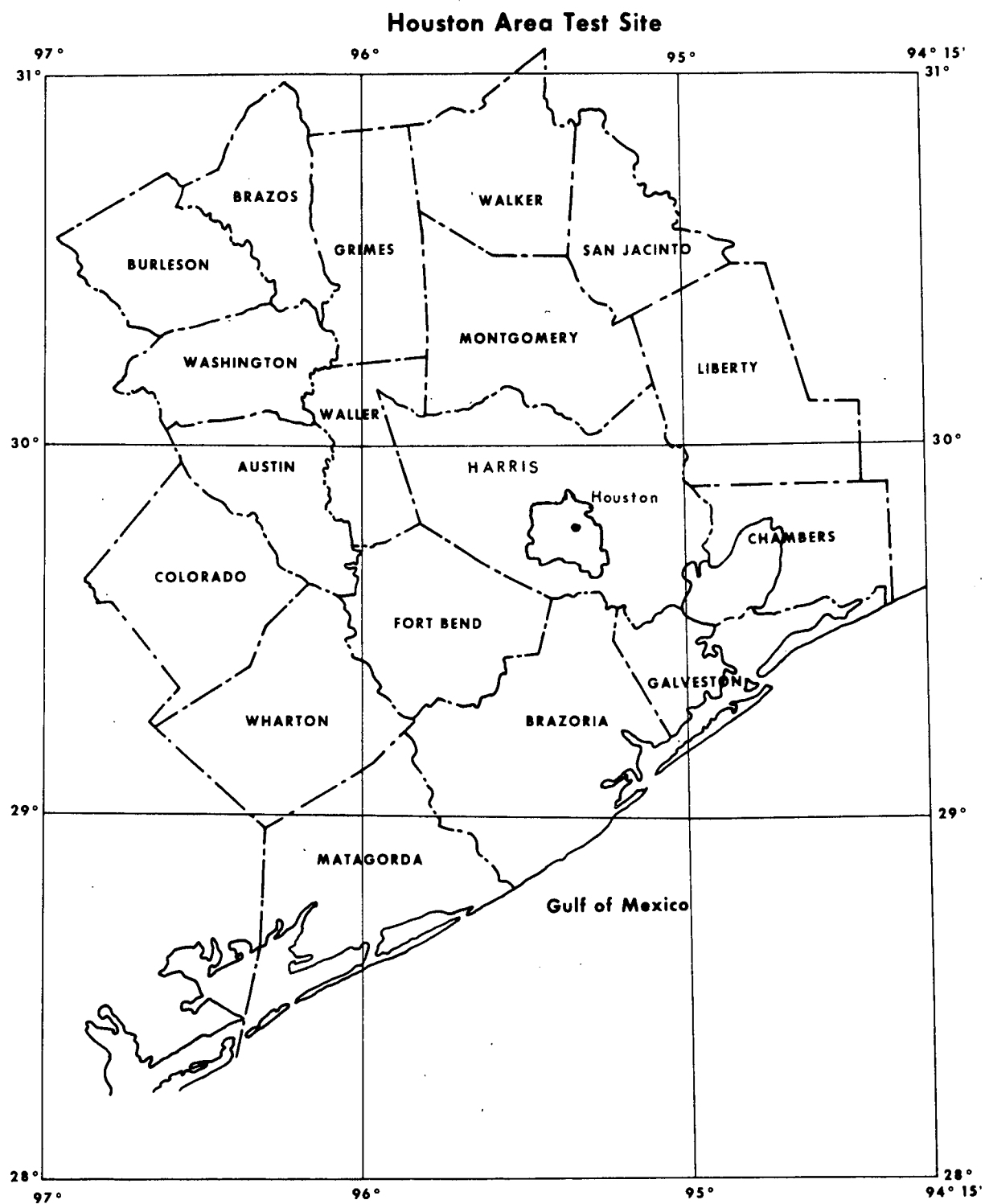


FIGURE 1

governmental representatives at various levels from municipal to federal.

Chapter III presents the general outline of the method of analysis used to evaluate and select the potential sites. Chapter IV recounts the results of the application of the method of analysis to five counties intimately involved with the growth of the greater Houston metropolitan area.

Chapter V summarizes the application of the method of analysis to location of dredging spoil sites along the Houston Ship Channel.

Chapter VI describes the work proposed for the second year of the project.

CHAPTER I

REMOTE SENSING

Introduction

Remote sensing is the name given to the technique of gathering information about an object which is remotely situated from the sensors. Alternatively, remote sensing means feeling, measuring, or imaging some sensation or characteristic of an object without being in physical contact with the object. The data and information obtained by remote sensing techniques supplement, but do not necessarily replace, information obtained from other sources, such as published reports, maps, and direct field investigation.

The method of remote sensing is rapid and time saving provided sufficient ground truth information is available to make interpretation of the remotely sensed data possible. For many civil engineering and geologic applications remote sensing is considered to be a more feasible and economical way of gathering data than by taking samples and making direct field studies. As far as site selection of sanitary landfills is concerned, the remote sensing technique affords opportunity for regional analysis of the ground conditions and all of the surrounding cultural features at the same time.

Aerial Photography

The taking of aerial photography, where the information is acquired in pictorial form without actually setting foot on the

ground being studied, is part of the general field of remote sensing. Small scale aerial photography in the scales of 1:60,000 and 1:120,000 in conventional color and color infrared positive transparencies were used in this study.

An aerial photograph gives an absolutely objective picture of the various elements of the landscape; that is, it shows in great detail the exact spatial distribution of all of the elements of the landscape. Small scale (high altitude) aerial photographs permit a continuity of observation which is not possible using photographs of large scale (low altitude). Many geologic features can be more easily recognized and associated with other significant features using small scale aerial photography.

Aerial photography presents a complete map, as well as a three-dimensional view of the area being covered when overlapping of frames permits stereoscopy to be used. When properly interpreted, stereoscopic aerial photographs reveal not only the topography but also considerable information concerning soil, geology, and other natural as well as manmade features.

Using the stereoscope, the effect of weathering on soil materials may be observed and the synoptic nature of the topography can be determined. Drainage pattern development can be traced; this indicates the type of soil present (for example, porous soils have no developed drainage patterns while impervious soils have well-developed drainage patterns). Furthermore, wherever the natural relationship between soil and vegetation remains practically undisturbed by man, the general soil type of a given area may be identified from the vegetation and the general drainage patterns shown on the photograph.

The aerial photograph records the appearance of the surface materials in such a way that they can be grouped into recognizable patterns, patterns that are repetitive in nature, where similar environmental conditions exist.

Color Photography

There are several special applications where color photography can be a very valuable tool for interpretation. These include:

1. Detailed land-use studies where differences in growth patterns at different times of exposure in the year are of significance.
2. River, estuarine and coastal studies where water and current variations may be expected to be reflected in terms of tonal variations in the photography.
3. Interpretation of and mapping of soils. Natural color aerial photography is considered the most useful film type for this because of the greater number of distinguishable color tones present and the various color hues of the soils and soil conditions.

Color aerial photography has some important advantages over other film types, namely: that smaller details can be identified on color photography than on black and white photography at the same scale, and that special filters can be used with the color film to increase the contrast between certain soils and facilitate soil mapping.

Infrared Photography

Infrared color photography is thought to be more suitable than standard color photography for many aerial photographic purposes. Color IR shows differences in vegetation vigor more clearly and

provides a slightly higher contrast between a water surface and its surroundings than conventional color film. Color IR is also useful for detecting alien fluids (pollution) in water bodies.

Green vegetation produces a very light colored image on color IR film. The image of water produced on color IR film is dark, and shadows are emphasized, although detail within the shadowed area is diminished or lost. The extent and vigor of vegetation as well as surface soil moisture conditions can be best inferred from color IR photography.

Application of Remote Sensing

The use of remote sensing techniques in the form of small scale color aerial photography and color IR photography are considered to be ideal for the preliminary selection of potential sites for sanitary landfills.

As the population of a given urban region increases and the region becomes more commercial or more residential, the location of new sites suitable for economical construction and operation of sanitary landfills becomes more difficult. Planning and evaluation of future site locations can be based on the interpretation of small scale photography as demonstrated by this investigation. Overlays of inferred geologic, engineering, and cultural features can be constructed and used with the photography to assist in the planning.

In aerial photographic interpretation, and in the planning required to find future landfill sites, a comparative analysis using, -- in addition to the overlays, -- maps, reports, and other available information is essential. This procedure generally involves:

1. Comparing what is seen in the aerial photographs with the maps that are available. This is done primarily for direction, distance, elevation, and place-to-place orientation.
2. Comparing photographs obtained at different times (months apart) in order to assess changes in land use.
3. Comparing photographs exposed in different portions of the energy spectrum for more thorough inference and understanding of a land region.
4. Comparing color and color IR photography of the same area to take better advantage of color cues for image identification and determination of significance.
5. Comparing photographs of one local area with those of another local area. This aids in identification of objects and conditions in inaccessible areas.

The final result of aerial photographic interpretation should be confirmed by some form of field check and/or verification by reference to a different type of information to insure correctness or reasonableness of the determination.

CHAPTER II

REMOTE SENSING DATA USED IN THIS INVESTIGATION

Introduction

The remote sensing information used throughout this investigation consisted of 9 inch by 9 inch positive transparencies from both regular color and color IR photography. The regular color transparencies had a scale of 1:120,000 while the color IR transparencies were 1:60,000. The scale of the photograph is the focal length of the camera divided by the altitude of the aircraft, both expressed in the same units.

Remote Sensing Data from Aircraft Mission No. 145.

The Mission No. 145 data listed in Table I was furnished by the Earth Observations Division of NASA-MSC for use in this project. The mission was flown over the Houston Area Test Site (designated as Test Site No. 175) using an instrumented RB 57 F type aircraft. While the aircraft was equipped with four different types of sensors, only the two types of photography were chosen for use in this study.

Remote Sensing Data from Aircraft Mission No. 191.

Only color IR photography from Mission No. 191 was requested for use in this investigation. Table II indicates the imagery furnished by the Earth Observations Division of

TABLE I
MISSION NO. 145 PHOTOGRAPHY

Altitude: 60,000 feet			
Flight Dates: November 3 and 18, 1970			
Overlap of frames in flight direction: 60%			
Sensor	RC-8/4L	Zeiss	
Film No.	SO-278	2443	
Film Type	Color	Color IR	
Filter No.	W-3	W-15	
Focal Length of Lens	6 inches	12 inches	
Flight Line No.	NASA Roll No.		Study Location
	Span of Frames Used		
8	94	96	Cleveland & Conroe
	9540~9546	148~162	
9	94	96	" "
	9510~9515	085~097	
10	94	96	Liberty
	9478~9480	024~030	
11	68	69	Houston
	8583~8589	028~040	
12	68	69	"
	8613~8621	086~102	
13	68	69	Houston, Ft. Bend Co.
	8644~8651	146~160	
14	68	69	Ft. Bend & Brazoria Cos.
	8673~8679	203~215	
15	68	69	Brazoria Co.
	8693~8696	245~253	
16	68	69	" "
	8723~8728	304~316	

TABLE II
MISSION NO. 191 PHOTOGRAPHY

Altitude: 60,000 feet

Flight Dates: November 11, 19, and 20, 1971

Overlap of frames in flight direction: 60%

Sensor: Zeiss Camera

Film No.: 2443

Film Type: Color IR

Filter No.: W-15

Focal Length of Lens: 12 inches

Roll Numbers: 11, 33, and 40

NASA-MSC. The flight lines of this mission were in-between those of Mission No. 145 so the 1:60,000 IR transparencies were used to study the areas between two adjacent flight lines of Mission No. 145. Thus, complete side-to-side coverage of the land area was assured.

References

1. Screening and Indexing Report, Mission 145, NASA-Manned Spacecraft Center, Houston, Texas, May 1971.
2. Mission Planning Report, Mission 191, NASA-Manned Spacecraft Center, Houston, Texas, October 1971.

CHAPTER III
PROCEDURE FOR LOCATING POTENTIAL
SANITARY LANDFILL SITES

Introduction

In this investigation major cities in Harris, Brazoria, Fort Bend, Liberty and Montgomery Counties were studied for potential sanitary landfill sites with the aid of remotely sensed information. The site selection procedure involved population projections to obtain expected waste quantities and total acreage needed, overlays of the terrain showing recommended haul distance radii, tentative sanitary landfill site selections, evaluation of relative site qualities using a numerical matrix rating system involving land use, drainage, soil type, road surface and site accessibility. Site visitations were made where warranted. This investigation was an exploratory effort, bringing a wide variety of information together to focus on the sanitary landfill site selection process.

The counties selected for study had a variety of topography, vegetation, population, and soil conditions. Locations of existing sanitary landfills were provided by the Texas State Department of Health, and are summarized in Table I.

Much has been accomplished in this investigation and the techniques described offer a new approach to site selection of sanitary landfills using small scale aerial photography, particularly infrared color transparencies.

TABLE I
EXISTING SANITARY LANDFILLS*

<u>County</u>	<u>Name of Site</u>	<u>Location</u>	<u>Approximate Date of First Use</u>
Brazoria	Alvin Landfill	N29°21', W95° 18'	1969
	Angleton Disposal Site	N29°11.5', W95°27.5'	1951
	Sweeny Landfill	N29°03.45', W95°41.90'	1946
	Brazoria-West Columbia Landfill	N29°05.35', W95°39.35'	1971
Fort Bend	Rosenberg Landfill	1 mi. E. of Rosenberg	1968
Harris	Baytown Disposal Site	Cedar Bayou & Kilgore Rds.	1959
	Pasadena Landfill	5200 Burk Street	1967
	American Refuse Systems Holmes Road Site		1929
	West University Place Site	9610 Ruffino Road	1958
	Bellaire Sanitary Landfill	9600 Ruffino Road	1956
	City of Houston Almeda-Genoa Road Landfill	Almeda-Genoa Road	?
	American Refuse Systems Site	S. of Garrett Rd. & E. of E. Houston Road	1971
Liberty	City of Cleveland Sanitary Landfill	N 30°16', W 95°07'	1969
	Hull-Daisetta Sanitary Landfill	W. of F.M. 770 between Hull and Daisetta	1970
Montgomery	Conroe Disposal Site	N30°22', W 95°24'	1958

*Source: Letter from Mr. David L. Houston, Chief of Environmental Development Program, Division of Sanitary Engineering, Texas State Department of Health, July 7, 1972.

Information on land disposal sites which do not meet the criteria for a sanitary landfill was not included, according to the letter.

Several potential sites and existing landfills were visited to acquire a better understanding of actual site conditions to compare with the remotely sensed data and the published technical information.

Houston-Galveston Area Council Population Projections

Table II contains the 1970 census information for major cities in Harris, Brazoria, Fort Bend, Liberty and Montgomery Counties. In addition, population projections by the Houston-Galveston Area Council are shown for 1980 and 1990. Cities expected to have 12,500 residents or more by the year 1990 were selected for analysis.

Total Waste and Total Acreage Projections

Table II also contains information on estimated total volume of solid waste (W) in the periods 1970-80 and 1980-90. These figures were obtained by adopting a reasonable estimate of volume of solid waste per capita per year for cities selected for analysis and multiplying by the average population between 1970-80 and 1980-90, respectively. Since the volume of solid waste is expected to increase, the factor was increased from 10 acre-feet per year per 10,000 population to 13 acre-feet per year per 10,000 in the second ten-year period.

The estimated total acreage required for solid waste disposal per 10 year period was computed by dividing the total waste volume (W) by an arbitrarily selected depth of six feet. Note that this six feet is totally solid waste whereas (with required Texas Health Department regulations of 2 feet of soil cover on top, 6 inches of soil cover between 2 foot layers of solid waste, and a 3 foot clay impervious bottom liner), the total excavation would be 12 feet to the landfill

TABLE II

POPULATION AND PROJECTED SOLID WASTE REQUIREMENTS

FOR SELECTED CITIES IN H.A.T.S.

County	Population			Volume of Waste (W)		Total Acreage = Acres/10 yr./ 10,000 pop. $W_x \times \frac{1}{6 \text{ ft. ave}} \times 10 \text{ yr.}$
	1970	1980	1990	Pave. x 10 ac.ft/ yr/10,000	Pave. x 13 ac.ft/ yr/10,000	1970-80 1980-90
<u>Harris</u>						
Baytown	43,980	68,300	100,000	56.1	109.2	93.5 182.5
Deer Park	12,773	19,500	29,300	16.14	31.7	26.9 48.8
Galena Park	10,479	12,000	12,500	11.24	15.9	18.8 26.6
Bellaire	19,009	19,800	21,300	19.41	26.6	32.4 44.4
Houston	1,235,936	1,452,700	1,828,100	1344.32	2200.0	2244.0 3680.0
West University	13,317	13,600	14,000	13.46	17.9	22.5 30.0
Pasadena	89,277	108,600	145,000	98.94	164.9	165.0 275.9
South Houston	11,527	15,050	19,200	13.29	22.1	22.3 37.2
<u>Brazoria</u>						
Alvin	10,671	15,500	25,000	13.08	19.8	21.8 33.1
Angleton	9,770	14,100	20,000	11.93	21.2	18.3 35.4

TABLE II (Cont'd)

County	1970	Population 1980	1990	Volume of Waste (W) 1970-80	1980-90	Total Acreage 1970-80	1980-90
Freeport	11,997	25,000	50,000	18.50	48.8	30.8	81.5
Lake Jackson	13,376	25,000	30,000	19.19	35.8	32.2	59.8
<u>Fort Bend</u>							
Missouri City	963	2,500	9,500				
Stafford	2,845	6,000	20,500				
Sugarland	3,318	7,000	15,000				
		<u>15,500</u>	<u>45,000</u>	<u>11.3</u>	<u>39.3</u>	<u>18.8</u>	<u>65.5</u>
Richmond	5,777	10,000	20,000				
Rosenberg	12,098	<u>18,000</u>	<u>30,000</u>				
		28,000	50,000	<u>22.9</u>	<u>50.7</u>	<u>38.2</u>	<u>84.5</u>
<u>Liberty</u>							
Cleveland	5,627	9,000	12,500	7.32	14.0	12.2	23.4
Liberty	5,591	8,000	15,000	6.80	14.9	11.3	25.0
<u>Montgomery</u>							
Conroe	11,969	19,000	33,000	15.49	33.8	25.8	56.5

bottom. For example from the top: 2 feet of final soil cover +
 2 feet of solid waste + 6 inches of soil + 2 feet of solid waste +
 6 inches of soil + 2 feet of solid waste + 3 feet of clay.

$$\text{Total Acreage} = W \times \frac{1}{6 \text{ ft. ave. depth}} \times 10 \text{ yr.}$$

It is understood that deeper landfills are being utilized in the Houston region. If a deeper site is developed, this simply cuts down on the land acreage needed. Thus, in this investigation the total acreage sought is on the proper side of conservatism. If in developing the better sites the landfills can be deeper than twelve feet, then less land will be needed.

Overlays

An overlay transparency was made to show land areas from 50 to 200 acres, see Table III. This was moved around on the frames of aerial photography to assist in searching for large tracts within the desired hauling radius.

Other overlays were used, for example, to indicate hauling radius, residential developments or industries, well locations, soil types, existing sanitary landfill sites, etc. These were constructed as required.

Haul Distance Limits for Cities

An analysis of haul distance from the approximate centroid of the city to existing sanitary landfills for cities in the Houston area indicated a definite trend in haul distance vs. population of city. These figures of haul distance were increased slightly to recognize

TABLE III
MAP AREAS NEEDED FOR LANDFILLS

Photography:

60,000 ft. altitude with 6" focus lens (Scale 1:120,000)

Positive color transparency, 9 inch x 9 inch format.

CORRESPONDING DIMENSIONS ON SO-278 PHOTOS

Area (acre)*	Dimension of Squares (ft x ft)	Corresponding Dimensions and Size of Square (in x in)
50	1,475 x 1,475	2.36/16 x 2.36/16 <input type="checkbox"/>
75	1,810 x 1,810	2.9/16 x 2.9/16 <input type="checkbox"/>
100	2,090 x 2,090	3.35/16 x 3.35/16 <input type="checkbox"/>
125	2,330 x 2,330	3.73/16 x 3.73/16 <input type="checkbox"/>
150	2,550 x 2,550	4.08/16 x 4.08/16 <input type="checkbox"/>
175	2,760 x 2,760	4.42/16 x 4.42/16 <input type="checkbox"/>
200	2,950 x 2,950	4.73/16 x 4.73/16 <input type="checkbox"/>

*1 acre = 4.356×10^4 ft²

a reasonable growth factor in future hauling distance and the suggested limits are as shown in Table IV.

TABLE IV
RECOMMENDED HAUL DISTANCES

<u>City Population</u>	<u>Radius - Miles</u>
10,000	4
25,000	6
50,000	8
100,000	10
500,000	15
>500,000	20

The haul distance was drawn on an overlay transparency to define the reasonable area within which to search for potential landfill sites.

Wind Consciousness

Blowing paper waste is the most commonly mentioned nuisance indicated by the general public concerning the presence of a landfill. In this investigation there was conscious effort to identify natural characteristics of the various sites that would serve as screens for potential landfills.

Figure 1 shows the prevailing wind directions for selected locations in Texas at different times during the year.* The lines in

*"The Report of the U.S. Study Commission (On Water Resources in) Texas ", Part II, Resources and Problems, March 1962.

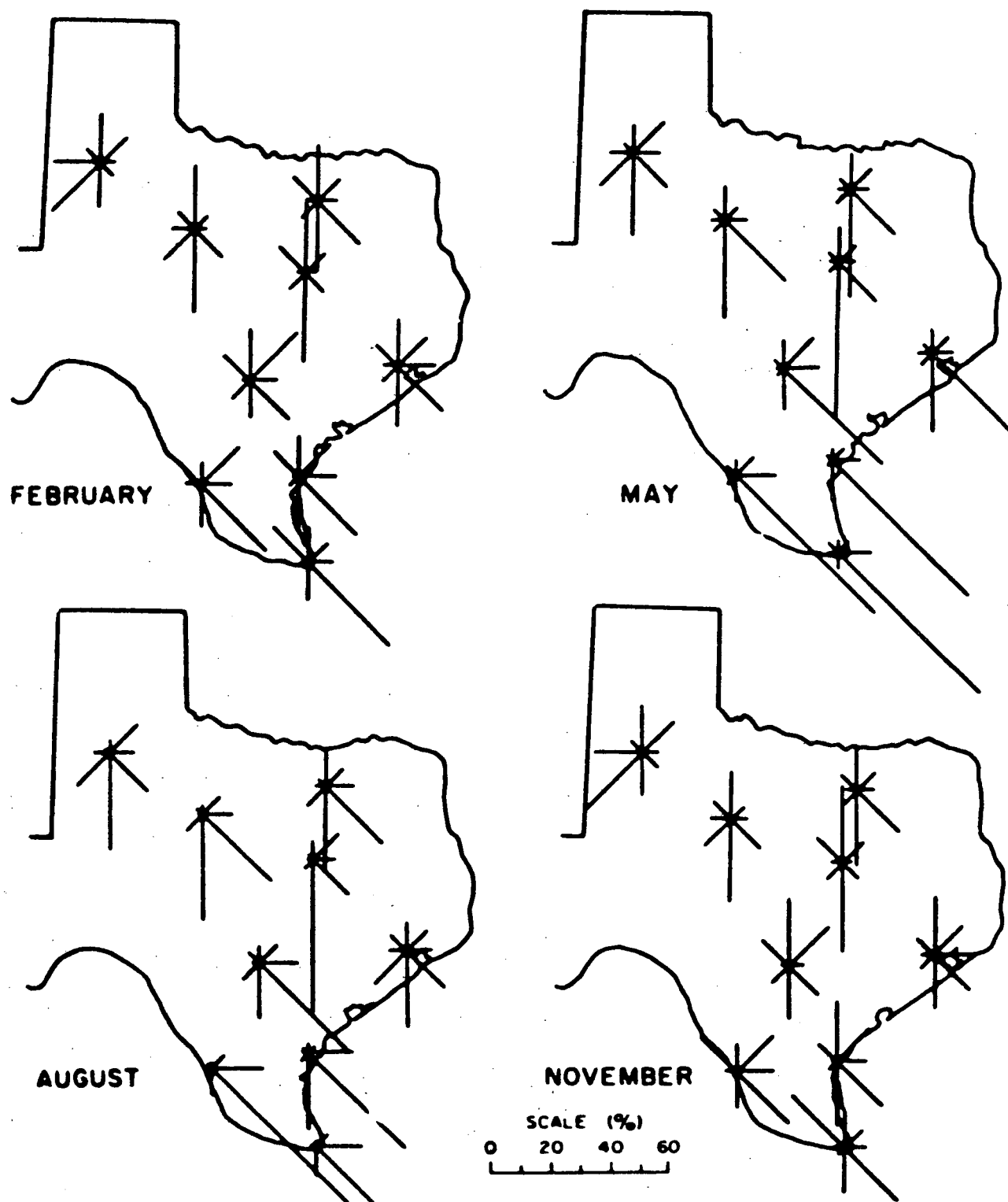


FIGURE 1. WIND ROSES

the figure extend toward the direction from which the wind was blowing. The percentage scale indicates the fraction of all time in the particular month that the wind was as shown.

Matrix Rating System for Ranking Landfill Sites

Table V shows the rating system devised for ranking alternative potential landfill sites. Table V is considered self-explanatory except for a discussion on soils which follows.

The rating of soil type is an important part of the total ranking procedure, as workability of soil at the site for daily cover and compaction indicates a preference of sandy loam over clay. Since detailed soil surveys to a depth of six feet have been performed in several counties in the Houston area by the U. S. Soil Conservation Service, the information recorded on photographs at their district offices was consulted. Also, a recent S.C.S. interim report* on the evaluation of soils for landfills was reviewed thoroughly.

Table VI is included as illustrative of the kind of detail coded onto the soil survey photographs.

More detail about soils is given in the Case Study of Brazoria County herein.

*"Soils - 30: Soil Limitations for Sanitary Landfills", Revision 2; Soil Conservation Service; U. S. Department of Agriculture, Temple, Texas, April 7, 1971.

TABLE V

MATRIX OUTLINE FOR ASSIGNING PRIORITIES TO LANDFILLS

	Value
1. Land Use	
Pasture land	0
Cultivated Land (productive agricultural land may be expensive vs. pasture land)	2
Woodland (value of timber, clearing cost)	5
Land occupied by structures	10
2. Drainage	
No drainage problems	0
Small, dry creek bed	2
Tributary next to site	5
High soil moisture	8
Small ponds on site	10
3. Soil Type (from General Soil Map and detailed soil survey photographs.)	
Sandy loam, loam, silt loam, sandy clay loam	0
Silty clay loam, clay loam, sandy clay, loamy sand	5
Silty clay, clay, muck, peat, gravel, sand	10
4. Road Surface	
Paved Road	
a. Interstate and state highway	0
b. County highway (division due to effect of heavy trucks on sub-base, and maintenance)	2
Bituminous surface road	3
Soil surface road	5
Graded and drained road	7
Bladed earth road	10
5. Accessibility	
Alternate route (in case primary route is closed)	0
No alternate route	3

TABLE VI
ALPHABETICAL IDENTIFICATION LEGEND
FOR DETAILED SOIL SURVEY PHOTOGRAPHS
Harris County, Texas

<u>Map Symbol</u>	<u>Mapping Unit Name</u>
1	Acadia very fine sandy loam
51, 52, U1, U2	Acadia-Urban land complex
* 33, 25	Addicks loam 1-1/2' organic matter-good loam, wetness-seasonal
533, 525, U33	Addicks-Urban land complex
1B	Atascocita fine sandy loam
3	Beaumont clay
53, U3	Beaumont-Urban land complex
* 4	Bernard clay loam
* 5	Bernard-Edna complex
55, 514*	Bernard-Edna-Urban land complex
54, U4-U24, U5	Bernard-Urban land complex
2	Bissonnet fine sandy loam
7	Boy loamy fine sand
* 9	Clodine fine sandy loam
59, U9	Clodine-Urban land complex
70	Crevasse sand
11	Crowley fine sandy loam
13, 12	Crowley-Gessner complex
511, 513, 519, U11, U19	Crowley-Urban land complex
14	Edna fine sandy loam
* 28, 31	Gessner loam (wetness--poorly drained)
35, 34, 29	Gessner complex
528, 531, U28, U31	Gessner-Urban land complex
36	Harris clay
8	Hatliff loamy fine sand
16	Hockley fine sandy loam, 0 to 1% slopes
16B, 16C	Hockley fine sandy loam, 1 to 4% "
23	Ijam clay

* Indicates soil type found on sites selected in Harris County.

19	Katy fine sandy loam
20	Kaufman clay
21, 15	Kenney loamy fine sand
521, 57	Kenney-Urban land complex
* 22	Lake Charles clay, 0 to 1% slopes
22B	Lake Charles clay, 1 to 5% slopes
522, U22	Lake Charles-Urban land complex
24	Midland clay loam
524	Midland-Urban land complex
6	Nahatcha loam
26, 32	Segno fine sandy loam, 0 to 1% slopes
26B	Segno fine sandy loam, 1 to 3% slopes
526, 516	Segno-Urban land complex
U50	Urban land
30	Vaiden clay, 0 to 1% slopes
30B	Vaiden clay, 1 to 5% slopes
530, U30	Vaiden-Urban land complex
10	Voss sand
37, 27	Waller loam
537	Waller-Urban land complex
17	Wockley fine sandy loam
517, U17	Wockley-Urban land complex

Summary of Procedures for Analyzing a Site

1. Select county and locate population centers.
2. Locate existing and completed landfill sites on photography.
3. Use a haul distance from city center as shown in Table IV. Draw a circle on the overlay using the haul radius and the urban centroid as center. Draw existing city limits on the overlay.
4. Use photography to observe natural and man-oriented land use characteristics (e.g., pastures, cultivated land, forested land) for general evaluation.
5. Review major roads from various highway maps of the region.
6. Block out a distance (preferably 1,000 feet) from nearest lake, creek, bayou or river and refer to flood inundation maps.
7. Make transparency of water well locations in the region from U. S. Geological Survey maps. Sanitary landfills should be located no closer than 500 feet. This will be used as a general guide. The aerial photography will be used directly to locate dwellings. Each house will be considered to have its own private well.
8. Obtain general topography map of 10 foot contours, or smaller if available. For coastal or flat areas, swells are the best topographic locations for situating potential sites to insure maximum height above the ground water table.
9. Obtain General Soil Map and observe soil types around population center.
10. Use detailed soil survey maps (photographs) for more specific soil evaluation.
11. Review Geologic Atlas of Texas (e.g., Houston Sheet, 1968) for general geology below 6 foot depth.
12. Use population and land requirement data as in Table II to determine suitability of area size.
13. Use photography to study the specific, existing roads around the proposed potential site.
14. Look for screening of the site by natural vegetation and landform features.
15. Look for cultural (social) features such as reservoirs, cemeteries, schools, etc., which could cause political and public relations problems.
16. Make a field check as a terminal step, if this seems warranted.

CHAPTER IV

CASE STUDIES OF SELECTED COUNTIES

CASE STUDY OF HARRIS COUNTY

Metropolitan Houston so dominates this county that Harris County was arbitrarily divided into ten segments for study. Each of these segments will be briefly discussed. The segments are: Pasadena, Galena Park, Baytown, South Houston, Deer Park, Bellaire, West University, and three wedge-shaped areas of Houston identified as South, North, and West wedges. While all of the area of the county, or of greater Houston, is not covered within these segments, the coverage is sufficient to show the need for reserving future landfill sites all around the county.

The potential sites selected for study in Pasadena will be identified by means of a plastic overlay on an aerial photograph of the Pasadena vicinity. Because of the expense it was not possible to do this for all ten segments of this investigation, so the potential sites in the others will only be described. Again because of expense the potential sites located in the case studies of counties adjacent to Harris are marked by white polygons and Roman numbers on the aerial photographs for those counties.

PASADENA

A. General Description

The city of Pasadena is bounded on the north by the Houston Ship Channel; on the east by the city of Deer Park; on the south by Ellington Air Force Base; on the southwest by State Highway 3, and the city of South Houston; and on the west by industrial and residential development of the City of Houston. The 1970 population was 89,277.

The population is projected to increase to 108,600 by 1980, and 145,000 by 1990.

The land seemingly most available for sanitary landfill use is to the southeast. This is the only open area in the Pasadena area since the City of Houston encompasses the western section and the Ship Channel negates the northern area.

There are several major streets which run southeast - northwest. The major street is Red Bluff Road. Another possibility for access to landfills is on the southern Pasadena border where South Shaver Street runs into Allen-Genoa Road which connects with the Genoa-Red Bluff Road to the East.

B. Specific Site Locations

Four potential sites were selected which are:

- (a) Site 1. East of Burke Street; land available for 1980 requirement only.
- (b) Site 2. South of Genoa-Red Bluff Road; land available for 1990 requirement.
- (c) Site 3. East of Red Bluff Road and south of Fairmont Parkway; land available for 1980 requirement only.
- (d) Site 4. South of Fairmont Parkway and west corner of Bay Area Boulevard.

C. Matrix Rating System

Table I shows the numerical values of the four potential sites.

TABLE I
MATRIX RATING SYSTEM FOR LANDFILL SITES
PASADENA, TEXAS

Criteria	Sites			
	1	2	3	4
Land Use	0	3	3	3
Drainage	5	0	3	5
Soil Type	5	10	1	1
Road Surface	0	0	5	0
Accessibility	0	0	3	0
Totals	10	13	15	9
Area of Site	132	230	172	232
Area Needed	1970-80			165.0 acres
Area Needed	1980-90			<u>275.9</u> acres
	Total			440.9 acres

A numerical value of 5 was given for the drainage at Site 1 due to the presence of two ponds found in this area on the photography. The value for drainage at Site 3 was set at 3 because of the location of a drainage ditch on the south side of the area. The value of 5 for drainage at Site 4 was due to the presence of ditches in the center and western portion of the area that were detected in the aerial photography.

D. Final Recommendations

Sites 1 and 4 appear to be the better potential sites. On-site inspection and determination of land value would be required in order to determine the final selection.

GALENA PARK

A. General Description

Galena Park is bounded on the south and southeast by the Houston Ship Channel; on the west by residential and industrial development of the city of Houston; and on the northwest by Jacinto City. Interstate highway I-10 on the north and Greens Bayou to the northeast offer problems for refuse truck hauling as to crossings.

The land seemingly most available for sites would be to the northeast beyond Greens Bayou along Wallisville Road and perhaps some land to the north of the city. In examining the color transparency photography, there is very little available land within the recommended haul distance radius of 6 miles from the city center. However, land for sites is available just beyond that radius to the northeast. Thus relaxation of the 6 mile radius would be desirable for this particular case. Galena Park would appear to have somewhat higher hauling costs than other cities of similar population due to its site constraints.

The population of Galena Park is not expected to increase much from the 1970 value of 10,479. According to projections of the Houston-Galveston Area Council, by 1980 the population will be 12,000, and by 1990 only 12,500.

B. Specific Site Locations

Three potential sites were selected which are:

- (a) Site 1. East of Oates Road between Wallisville Road and Interstate I-10; capacity for only 1980 requirements; site is very close to the city.
- (b) Site 2. Along Holland Avenue north to Market Street and east to Uvalde Road north to Wallisville Road. The site is north of Wallisville Road before the crossing with Carpenters Bayou.
- (c) Site 3. Farther east from Site 2 on Wallisville Road, past Carpenters Bayou with the site being located south of Wallisville Road.

C. Matrix Rating System

Table II shows the numerical values of the three potential sites.

TABLE II
MATRIX RATING SYSTEM FOR LANDFILL SITES
GALENA PARK, TEXAS

Criteria	Sites		
	1	2	3
Land Use	0	0	0
Drainage	5	0	8
Soil Type	10	10	5.8
Road Surface	0	0	3
Accessibility	0	0	3
Totals	15	10	19.8
Area of Site	22	41	87
Area Needed		1970-80	18.8 acres
Area Needed		1980-90	<u>26.6</u> acres
		Total	45.4 acres

The matrix rating system indicates a value of 5 for drainage for Site 1 due to a canal on the north side of the site, also a value of 8 for Site 3 due to much moisture on the site. This moisture condition for Site 3 was quite evident from the color IR photography and is an excellent example of the benefit gained from this form of remotely sensed information.

D. Final Recommendations

Site 2 has the lowest numerical rating and therefore appears to be more desirable than the other two. The soil type, Beaumont clay, is a disadvantage to the site since clay is not a good workable soil for daily cover over the compacted solid waste.

BAYTOWN

A. General Description

Baytown is bounded on the east by Cedar Bayou, which serves as a county line between Harris and Chambers Counties; on the south by the Houston Ship Channel; on the west by a series of small bays, lakes, and a river including Burnett Bay, Old River, Crystal Lake, Scott Bay, Peggy Lake, Black Duck Bay, San Jacinto Bay and Tabbs Bay; and on the north by Interstate Highway I-10.

Baytown had a population of 43,980 in 1970. Projections by the Houston-Galveston Area Council indicate an increase by 1980 to 68,300 and by 1990 to 100,000.

From an economic standpoint, based on land value and hauling distance, it would appear that the best sanitary landfill sites would be located north of I-10. Examination of aerial photography of the region, avoiding oil field areas, drainage networks (including canals), residential and/or subdivision areas, and forested areas, led to the selection of three potential sites. An effort was made to locate these areas to utilize the major roads to minimize the travel time while staying within a ten mile haul radius. The major roads include Garth Road and Crosby Road.

B. Specific Site Locations

- (a) Site 1. West of Crosby Road, north of I-10, near airport.
- (b) Site 2. East of Crosby Road, north of I-10, northeast of airfield.
- (c) Site 3. West of Garth Road, north of I-10, west of airfield.

C. Matrix Rating System

Table III shows the numerical values of the three potential sites.

TABLE III
MATRIX RATING SYSTEM FOR LANDFILL SITES
BAYTOWN, TEXAS

Criteria	Sites		
	1	2	3
Land Use	0	2	0
Drainage	0	5	10
Soil Type	10	10	9
Road Surface	5	5	3
Accessibility	0	3	0
Totals	15	25	22
Area of Site	143	217	473
Area Needed	1970-80	93.5 acres	
Area Needed	1980-90	<u>182.5</u> acres	
	Total	276.0 acres	

The value of 10 for drainage at Site 3 is due to the location of two ponds in the vicinity. The value of 5 for drainage at Site 2 resulted from general surface wetness and a high ground water table which was reflected in the color IR photography.

D. Final Recommendation

According to the rating system, Site 1 has the best potential for a sanitary landfill operation. Sites 2 and 3 have high rating values and appear to have too many disadvantages.

SOUTH HOUSTON

A. General Description

South Houston is bounded on the north and east by Pasadena, and on the north, west and south by residential and commercial developments of Houston.

South Houston had a 1970 population of 11,527. The projected population for 1980 is 15,050 and for 1990 it is 19,200.

The haul radius for South Houston encompasses two potential sites for Pasadena. Thus it would seem beneficial for the two cities to arrange some type of cooperative or joint waste handling program. These two sites can be reached via Allen-Genoa Road to Genoa-Red Bluff Road. Another potential route could be along Highway 3 to South Shaver Street and on to Alameda-Genoa Road to the west.

B. Specific Site Locations

The first two potential sites are Sites 1 and 2 for Pasadena.

The other two possible sites are:

(a) Site 3. North of Hall Road; access from South Telephone via Alameda-Genoa Road; site south of Hobby Airport.

(b) Site 4. Southwest of Hall Road from Choate Road; access from Highway 1959 via Highway 3; site north of Apple Creek.

C. Matrix Rating System

Table IV shows the numerical values of the four potential sites.

TABLE IV
MATRIX RATING SYSTEM FOR LANDFILL SITES
SOUTH HOUSTON, TEXAS

Criteria	Site			
	1	2	3	4
Land Use	0	3	0	3
Drainage	5	0	0	5
Soil Type	5	10	10	10
Road Surface	0	0	0	0
Accessibility	0	0	0	0
Totals	10	13	10	18
Area of Site	132	230	24	26
Area Needed	1970-80		22.3 acres	
Area Needed	1980-90		<u>37.2</u> acres	
	Total		59.5 acres	

The value of 5 for drainage at Site 1 is due to two small ponds within the area identified on the color IR photography. Site 4 also had a value of 5 for drainage due to a drainage ditch being located just to the east of the site. This could cause some drainage - moisture problems for that site..

D. Final Recommendations

Sites 1 and 3 seem to be the preferable sites for South Houston. Site 1 could be shared with Pasadena. Site 3 may be the best site if the clayey soil conditions can be overcome.

DEER PARK

A. General Description

Deer Park is bounded by the Houston Ship Channel on the north, by Pasadena on the west, and by La Porte and Lomax on the east.

Deer Park had a population of 12,773 in 1970. The population is expected to grow to 19,500 by 1980. The 1990 projected population is 29,300.

The land seemingly most available for sanitary landfill use is to the south. Four of the potential sites are within the Pasadena haul radius, which indicates the possibility of these cities sharing landfill sites in the future. Sites 1 and 2 could be utilized by South Houston as well as Pasadena and Deer Park.

The major highway bisecting the city is the LaPorte Freeway, State Highway 225. However, it appears that the best route to available land would be Red Bluff Road via Center Street or Luella Avenue and Spencer Highway.

B. Specific Site Locations

In addition to the four Pasadena potential sites (see Pasadena section), the following site was selected:

- (a) Site 5. North of LaPorte Freeway about midway between Tidal Road on the west and Highway 134 on the east.

C. Matrix Rating System

Table V shows the numerical values of the five potential sites.

TABLE V
MATRIX RATING SYSTEM FOR LANDFILL SITES
DEER PARK, TEXAS

Criteria	Site				
	1	2	3	4	5
Land Use	0	3	3	3	0
Drainage	5	0	3	5	0
Soil Type	5	10	1	1	10
Road Surface	0	0	5	0	0
Accessibility	0	0	3	0	0
Totals	10	13	15	9	10
Area of Site	132	230	172	232	101
Area Needed		1970-80		26.9 acres	
Area Needed		1980-90		<u>48.8</u> acres	
		Total		75.7 acres	

D. Final Recommendations

Site 4 has the lowest rating. There could be minor problems due to cultivated land, drainage, and a soil type other than sandy loam. Site 5 has a good rating except for the disadvantage of a clay soil type. However, Sites 1 and 5 are also close in the rating with a value of 10 each. Site 1 could be shared with Pasadena and South Houston. Site 4 could be shared with Pasadena. Site 5 is completely within the limit of haul radius of Deer Park only.

BELLAIRE

A. General Description

Bellaire is surrounded by residential areas of the City of Houston on the north, west, and south and by West University Place on the east. The loop highway I-610 divides the city into two major sections.

The population of Bellaire in 1970 was 19,009. The estimated population for 1980 is 19,800 and for 1990 is 21,300. Thus, the city is not expected to grow much since it is completely contained in its present geographical area.

The land seemingly most available for sanitary landfill use is southwest from the city. The major streets are Bellaire leading west and Bissonet to the southwest until it passes Gessner at which point it then parallels Bellaire to the west. Chimney Rock, a major north and south street, connects to South Main which leads to the southwest; this is another available route for landfill access. Still another route could possibly be via South Post Oak Road and loop I-610, then along South Main.

B. Specific Site Locations

After examining the photography and noting the residential developments around Sharpstown it appears that the western routes and land possibilities offer little promise for sites. Four potential sites were selected.

- (a) Site 1. North of South Main on Fondren Road.
- (b) Site 2. South of South Main west of South Post Oak Road.
- (c) Site 3. South of Bellaire and west of Roark Road.

(d) Site 4. East of Alameda Road along an unnamed road which is north and parallel to Mowery Road north of Sims Bayou and west of proposed north-south freeway.

C. Matrix Rating System

Table VI shows the numerical values of the four potential sites.

TABLE VI
MATRIX RATING SYSTEM FOR LANDFILL SITES
BELLAIRE, TEXAS

Criteria	Site			
	1	2	3	4
Land Use	2	0	2	2
Drainage	0	0	0	5
Soil Type	10	5	10	10
Road Surface	0	3	0	7
Accessibility	0	3	0	3
Totals	12	11	12	27
Area of Site	33	38	39	34
Area Needed	1970-80		32.4 acres	
Area Needed	1980-90		<u>44.4</u> acres	
	Total		76.8 acres	

The drainage at Site 4 was given a rating of 5 due to an irrigation ditch bordering the site.

D. Final Recommendations

Sites 1, 2, and 3 are so close together it would be difficult to choose one site over another without a detailed engineering survey and other information for analysis. Sites 2 and 4 could also be used by West University Place, although Site 4 has so many disadvantages perhaps it should not be considered a likely site.

WEST UNIVERSITY PLACE

A. General Description

Like Bellaire, West University Place has a fixed geographical boundary. It is surrounded by Houston on three sides and bordered by Bellaire on the west. Therefore the population is not expected to change very much. West University Place had a population of 13,317 in 1970. The population projection for 1980 is 13,600 and for 1990 it is 14,000.

B. Specific Site Locations

Sites 2 and 4 for Bellaire are also within the haul radius for West University Place. Not much other vacant land is available for landfills. Two other sites were initially selected, but were outside the haul radius and have been eliminated from consideration.

C. Matrix Rating System

Table VII shows the numerical values for the four potential sites.

TABLE VII
MATRIX RATING SYSTEM FOR LANDFILL SITES
WEST UNIVERSITY PLACE, TEXAS

Criteria	Site			
	1	2	3	4
Land Use	E	0	E	2
Drainage	l	0	l	5
Soil Type	i	5	i	10
Road Surface	n	3	n	7
Accessibility	a	3	a	3
	t		t	
	e		e	
	d		d	
Totals		11		27
Area of Site		38		34
Area Needed	1970-80		22.5 acres	
Area Needed	1980-90		<u>30.0</u> acres	
	Total		52.5 acres	

As noted in the Bellaire section, a nearby irrigation ditch was the reason for assigning a rating of 5 on drainage for Site 4.

D. Final Recommendations

Site 2, if arrangements were made to share it with Bellaire, is the clear-cut choice for a West University Place landfill site.

HOUSTON

A. General Description

Since the region within a 20 mile haul distance radius from the city center contains so much land to be considered, basic assumptions were made to assist in the evaluations. The city area was divided into segments or wedges formed by major highways emanating south, west, and north from the central business district. Houston is bounded on the east by the Houston Ship Chennel and large industrial developments as well as the cities of Pasadena, Galena Park, South Houston, etc.

The population of Houston is projected to increase from 1.2 million in 1970 to 1.4 and 1.8 million in 1980 and 1990, respectively. The city will need approximately 12 sites of about 200 acres each to last until 1980, and an additional 19 sites of about 200 acres each for 1990. For the three wedges formed to the north, west, and south, about four sites of 200 acres or more will be needed for each wedge to last until 1980 and seven more sites between then and 1990.

A1. HOUSTON -- SOUTH WEDGE

B. Specific Site Locations

Nine potential sites were located between Highways 288 and 35 to the south of Houston. The sites are:

Harris County

(a) Site 1. West of Furman Road, north of Almeda-Genoa Road, east of Highway 288; also south of Sims Bayou and northeast from Canterbury Village.

(b) Site 2. West of Cullen Boulevard, north of Almeda-Genoa Road and east of Furman Road at the north corner of Fellows Road.

(c) Site 3. West of Cullen Boulevard and north of Fellows Road adjacent to Site 2.

(d) Site 4. East of Highway 288 off Riley Road, east of Karalis Road, and north of Clear Creek.

Brazoria County

(e) Site 5. East of Highway 288, west of Airline Road and south of Clear Creek.

(f) Site 6. East of Highway 288, east of Airline Road and north of Wood Road.

(g) Site 7. East of Chololate Bayou Road, and south of Wood Road.

(h) Site 8. West of Pearland, south of Highway 518, and east of Manuel-Pearland Road.

(i) Site 9. South beyond Pearland, and along Pearland-Sites Road which bisects the large site; north of Chigger Creek.

C. Matrix Rating System

Table VIII shows the numerical values of the none potential sites.

D. Final Recommendations

A detailed soil survey was not available for Sites 5 - 9.

However, it is believed that Site 9 may be slightly more desirable than Sites 5 or 8. For Sites 1 - 4, Site 2 has the lowest rating although Site 3 would serve almost as well. Drainage, soil type, and road surface are common problems to the sites in the South Houston Wedge.

A2. HOUSTON -- NORTH WEDGE

B. Specific Site Locations

Ten potential sites were located in the North Wedge between

Highways 149 and 90. The sites are:

- (a) Site 1. East of Bammel Road, north of West Montgomery Road, and south of Greens Bayou.
- (b) Site 2. North of Spears Road, east of Steubner-Airline Road; east of corner with Walters Road.
- (c) Site 3. West of Hardy Road near the railroad, north of Rankin Road, and east of I-45; north of corner with Farrell Road.
- (d) Site 4. West of I-45, south of Aldine Road.
- (e) Site 5. North of Rankin Road, and east of I-45.
- (f) Site 6. A short distance east of Hardy Road, south of Rankin Road.
- (g) Site 7. West of Highway 59, north of Green Road, east of airport and west of Lee Road.
- (h) Site 8. West of Highway 59, north of North Belt Drive, and east of Lee Road; north of Reinhardt Bayou.
- (i) Site 9. East of and adjacent to El Dorado Golf Club on the south side of North Belt Drive.
- (j) Site 10. East of Farrell and Aldine-Westfield Road immediately adjacent to airport; south of Maguire Road.

C. Matrix Rating System

Table IX shows the numerical values of the ten potential sites.

D. Final Recommendations

Sites 6 and 8 have the lowest ratings. These sites should be studied in detail for early development. Sites 1, 2 and 5 appear to be similar in many respects. Site 7 has a rating of 10 but it is believed that more detailed analysis is needed to make firm the

TABLE IX

MATRIX RATING SYSTEM FOR LANDFILL SITES

HOUSTON -- NORTH WEDGE

Criteria	Site									
	1	2	3	4	5	6	7	8	9	10
Land Use	2	2	0	2	0	2	2	0	2	0
Drainage	2	2	8	8	5	0	0	2	2	5
Soil Type	3*	3*	5	1	5*	3*	8*	1	5*	2*
Road Surface	3	3	2	5	0	0	0	2	2	0
Accessibility	0	0	3	3	0	0	0	0	0	0
Totals	10	10	18	19	10	5	10	5	11	7
Area of Site	94	289	178	79	120	390	237	184	126	86
	For 1970-80 and 1980-90 area needed, see "General Description" of Houston.									
	*More than one soil type on site. This represents an average valuation of several soils weighted by percentage of area and soil type.									

rating. Site 9 has a rating of 11 and perhaps the potential soils difficulty is not as serious as anticipated. The accessibility rating of 3 for Site 3 is caused by a railroad crossing which could be an obstacle to trucks travelling to and from the landfill. Engineering site surveys and other information would be required before a final choice of certain sites over others could be made.

A3. HOUSTON -- WEST WEDGE

B. Specific Site Locations

Eleven potential sites were located in the West Wedge between Highways 59 and 149. The sites are:

- (a). Site 1. South of Clay Road, between Gessner and Brittmore Road.
- (b) Site 2. South of Westheimer near corner with Dairy Ashford Road.
- (c) Site 3. Southeast corner of Addicks-Howell Road at Alief Road.
- (d) Site 4. West of Addicks-Howell Road, south of Westheimer, and north of Brays Bayou.
- (e) Site 5. South of Goar Road between Addicks-Howell Road and Dairy Ashford Road.
- (f) Site 6. North side of Alief Road a few miles past the crossing with Addicks-Howell Road.
- (g) Site 7. North of Highway 1960, about a mile northeast of Hempstead Road.
- (h) Site 8. South of Highway 1960, east of Jones Road; south of Taub Road.
- (i) Site 9. West of Reed Road, north of Hempstead Road, north of White Oak Bayou. A road would have to be built to the site.

(j) Site 10. North of Taub Road, west of West Montgomery, near community of North Houston.

(k) Site 11. South of Mulberry and north of Collier Airport, west of West Montgomery Road.

C. Matrix Rating System

Table X shows the numerical values of the eleven potential sites.

D. Final Recommendations

Sites 7, 10, and 11 have the three lowest ratings. The value of 5 for drainage for Site 7 is due to a ditch on the north side. Sites 10 and 11 are situated relatively close to one another and a landfill could be operated nicely at either site, although the access to Site 11 would have to be developed. Sites 1, 4 and 5 appear to be quite satisfactory, although the land use in the vicinity of the latter two would pose problems not expected of Site 1. Sites 2 and 3 have canals adjacent to them. Site 6 has a creek on the north side. Sites 2, 3, 6 and 9 probably should be rejected from the refined analysis of these potential sites.

TABLE X

HOUSTON -- WEST WEDGE

Criteria	1	2	3	4	5	6	7	8	9	10	11
Land Use	0	3	3	3	3	3	3	3	3	0	0
Drainage	2	10	8	2	2	8	5	2	5	0	0
Soil Type	10*	10	10*	10*	10*	10*	4*	10	8*	10	5*
Road Surface	3	0	0	0	2	2	0	3	10	3	3
Accessibility	0	0	0	0	0	0	0	0	3	0	0
Totals	15	23	21	15	17	23	12	18	29	13	11
Area of Site	251	321	413	186	201	111	275	272	279	193	111

For 1970-80 and 1980-90 area needed, see "General Description of Houston."

*More than one soil type on site. This represents an average valuation of several soils weighted by percentage of area and soil types.



PASADENA, HARRIS CO.

57-a

CASE STUDY OF BRAZORIA COUNTY

Brazoria County is located in the Coastal plain of southeastern Texas adjacent to the Houston metropolitan area. The county is bordered on the west by Matagorda, Wharton, and Fort Bend counties, bordered by Harris county on the north, Galveston county on the east and the Gulf of Mexico on the south. It is flat, coastal topography drained by the Brazos and San Bernard Rivers. The Brazos River flows through the central portion of the county. It empties into the Gulf near Freeport. The San Bernard River flows through the western portion of the area, and empties directly into the Gulf near Freeport.

The county seat is Angleton which is on Texas highways 288 and 35 about 42 miles southwest of Houston and 50 miles northwest of Galveston.

A. POPULATION

In 1970 the population of Brazoria county was 108,312. From 1900 until 1940 the county population remained somewhat stable but with the beginning of the chemical industry growth in 1940, the population began growing rapidly and is still doing so. See Table I for the population forecast.

TABLE I
POPULATION OF BRAZORIA COUNTY

<u>Year</u>	<u>Brazoria Co. Population</u>
1970	108,312
1975	133,860
1980	201,500
1985	280,000
1990	400,000
Source: "Population Projections" Gulf Coast Planning Region H-GAC April 1, 1972.	

B. PHYSIOGRAPHY AND CLIMATE

The elevation of all areas of the county lie below 50 feet above sea level. The level coastal plain has local relief of only a few feet.

The average annual precipitation is 44 to 48 inches. Most of the rainfall occurs in the latter part of February and in May. During the warm season from April to September, the rainfall averages from 20 to 28 inches. The average annual temperature is from 68° F to 70° F. The prevailing winds are from the southeast.

C. WATER AND DRAINAGE

The moderate to high rainfall and many perennial streams provide abundant water. Water for irrigating rice is obtained predominately from the streams. About 10 percent of it comes from underground aquifers. Ground water is abundant. Much of the land must be drained before it can be successfully used for general farm crops.

The drainage pattern is generally dendritic which is characteristic of flat areas of unconsolidated sands, clays, silts or gravels where the direction of headward stream erosion is largely a matter of chance. Because of the gentle unidirectional slope of the Gulf Coastal plain there is a trend for the drainage paths to become parallel and flow toward the Gulf.

D. SOILS

Information available at the Soil Conservation Office in Angleton was used to determine the soil characteristics of the various sites selected. At present 80 percent of the county has had a soil survey and the soil properties of the remainder can be estimated reliably. It should be noted that soil interpretations are only one criteria for recommending land uses. There are many other factors including the goals of a community, population growth, traffic intensities, and economy, to mention a few. In the case of locating sanitary landfills it may be desirable to overcome the limitations of the soil through proper design and planning of the operational activities.

Emphasis should be given to the importance of using agricultural soil survey information during the preliminary site evaluation for a sanitary landfill for it is believed that great savings can be realized at this starting point.

The soil survey of Brazoria County has not been published yet, however, soil maps drawn on aerial photographs taken by the Soil Conservation Service in 1952 and 1965 are available. The soil maps there are reliable for predicting the soil limitations of an area of several acres. Different kinds of soil can occur within short distances, and most maps are not detailed enough to supply precise information as to what will be found at a specific point.

The General Soil Map shows the different soil associations in a county. A soil association is a landscape that has a distinctive proportional pattern of soils. It normally consists of one or more major soils. The soils in one association may occur in another, but in a different pattern.

A general description of the soil associations in Brazoria county* are:

1. SABINE-GALVESTON-VESTON ASSOCIATION: Acid, alkaline and saline, sandy and loamy soils.
2. PLEDGER-MILLER (Saline) ASSOCIATION: Neutral and alkaline, saline clayey soils.
3. HARRIS-MOREY-CLODINE ASSOCIATION: Alkaline and saline, clayey and loamy soils.
4. LAKE CHARLES-BERNARD ASSOCIATION: Neutral clayey and loamy soils.
5. BERNARD-MOREY-CLODINE ASSOCIATION: Neutral and acid loamy soils.
6. BEAUMONT-MOREY-LAKE CHARLES ASSOCIATION: Acid and neutral, clayey and loamy soils.
7. EDNA-BERNARD ASSOCIATION: Acid and neutral, loamy soils.
8. MILLER-NORWOOD-PLEDGER ASSOCIATION: Alkaline, clayey and loamy soils.
9. MILLER-PLEDGER ASSOCIATION: Alkaline and neutral, clayey soils.
10. MILLER-NORWOOD ASSOCIATION: Alkaline, clayey and loamy soils.

The soil series (origins)** represented in these associations are:
BEAUMONT SERIES:

Very dark gray to gray, with or without brown mottling acid clay surface, 8 - 25 inches thick, over gray to light gray with distinct yellowish mottles, firm blocky to massive acid clay that grades into mottled light gray and olive very sticky and plastic massive acid

*Source: "General Soil Map of Brazoria County," Revised by Jack D. Crout, October 2, 1970.

clay. Nearly level (0 - 0.5% slopes).

BERNARD SERIES:

Grayish brown to dark gray crumbly and friable acid clay loam surface, 6 - 12 inches thick, over dark gray to grayish brown friable subangular blocky and granular neutral clay that grades into a very firm blocky weakly alkaline clay, 18 - 28 inches beneath the surface. Nearly level (0 - 1% slopes).

CLODINE SERIES:

Dark gray loam surface over a gray light clay loam slightly acid to alkaline sub-surface zone.

EDNA SERIES:

Gray to light gray friable acid sandy loam to clay loam surface, 8 - 12 inches thick, over gray compact blocky acid clay with small amount of brownish yellow mottling. Nearly level (0 - 1/2% slopes).

GALVESTON SERIES:

Light brownish gray to pale brown slightly acid to neutral fine sand surface, 3 - 8 inches thick, over pale yellow loose slightly acid fine sand with water table 3 - 4 feet beneath the surface in smooth areas. Nearly level to dunelike.

HARRIS SERIES:

Very dark gray clayey surface over a dark gray clayey sub-surface zone, changing to a gray clayey geologic zone at a depth of about 3-1/2 feet.

LAKE CHARLES:

Gray to very dark gray firm slightly acid to neutral clay surface, 12 - 36 inches thick, over gray, mottled with yellowish brown, very firm blocky slightly alkaline clay. Nearly level (0 - 0.5% slopes).

MILLER SERIES:

Dark reddish brown crumbly calcareous clay surface, 10 - 20 inches thick, over dark reddish brown crumbly subangular blocky calcareous clay. Moderately well drained, nearly level flood plains.

MOREY SERIES:

Very dark gray silty surface over a firm, gray silty clay loam sub-surface zone having common brownish mottles.

NORWOOD SERIES:

Reddish brown to dark reddish brown friable strongly calcareous silt loam to silty clay loam surface, 9 - 25 inches thick, over light reddish brown very friable granular silt loam or silty clay loam several feet thick. Well drained, nearly level flood plains, seldom flooded.

PLEDGER SERIES:

Very dark gray to black crumbly and friable noncalcareous clay surface, 10 - 20 inches thick, over reddish brown very firm massive strongly calcareous clay. Nearly level (0 - 1% slope).

SABINE SERIES:

Dark grayish brown to grayish brown granular friable acid loamy sand surface, 10 - 12 inches thick, over pale brown mottled with brownish yellow and yellowish brown, structureless friable acid loamy sand with weakly alkaline sandy deposits of old coastal beaches at approximately 50 inches beneath the surface. Nearly level (0 - 1% slope).

VESTON SERIES:

Dark gray fine sandy loam surface over a gray loam and silty clay loam sub-surface zone. Strata of different textures are common for thicknesses up to about 50 inches.

**Source: "Soil Series of the United States, Puerto Rico and the Virgin Islands: Their Taxonomic Classification" Soil Conservation Service, USDA, Issued August 1972.

E. LAND USES

Not all land is suitable for use as a sanitary landfill site. So before potential landfill sites can be chosen, a form of land inventory must be prepared. Certain types of soil, geological conditions, transportation facilities, proximity to developed areas, and cost of the land are restraints on the use of a piece of property otherwise ideally situated for disposal purposes. Projected future use of some land areas will also be significant in determining the suitability of a land site.

Land use is divided into four major categories. These include: cropland, including both dry cropland and irrigated; pastureland, including rangeland; woodland, and urban lands that are devoted mainly to uses other than agricultural. The definitions of the major land uses are as follows:

CROPLAND -- Land currently tilled, idle cropland, rotation pasture and cover crops. Cropland includes all tame hay, land in vegetables, fruits and nuts.

PASTURE AND RANGE -- Land in grass and other long term forage growth that is used primarily for grazing.

FOREST AND WOODLAND -- Land which is at least 10 percent stocked by forest trees of any size and capable of producing timber or other wood products.

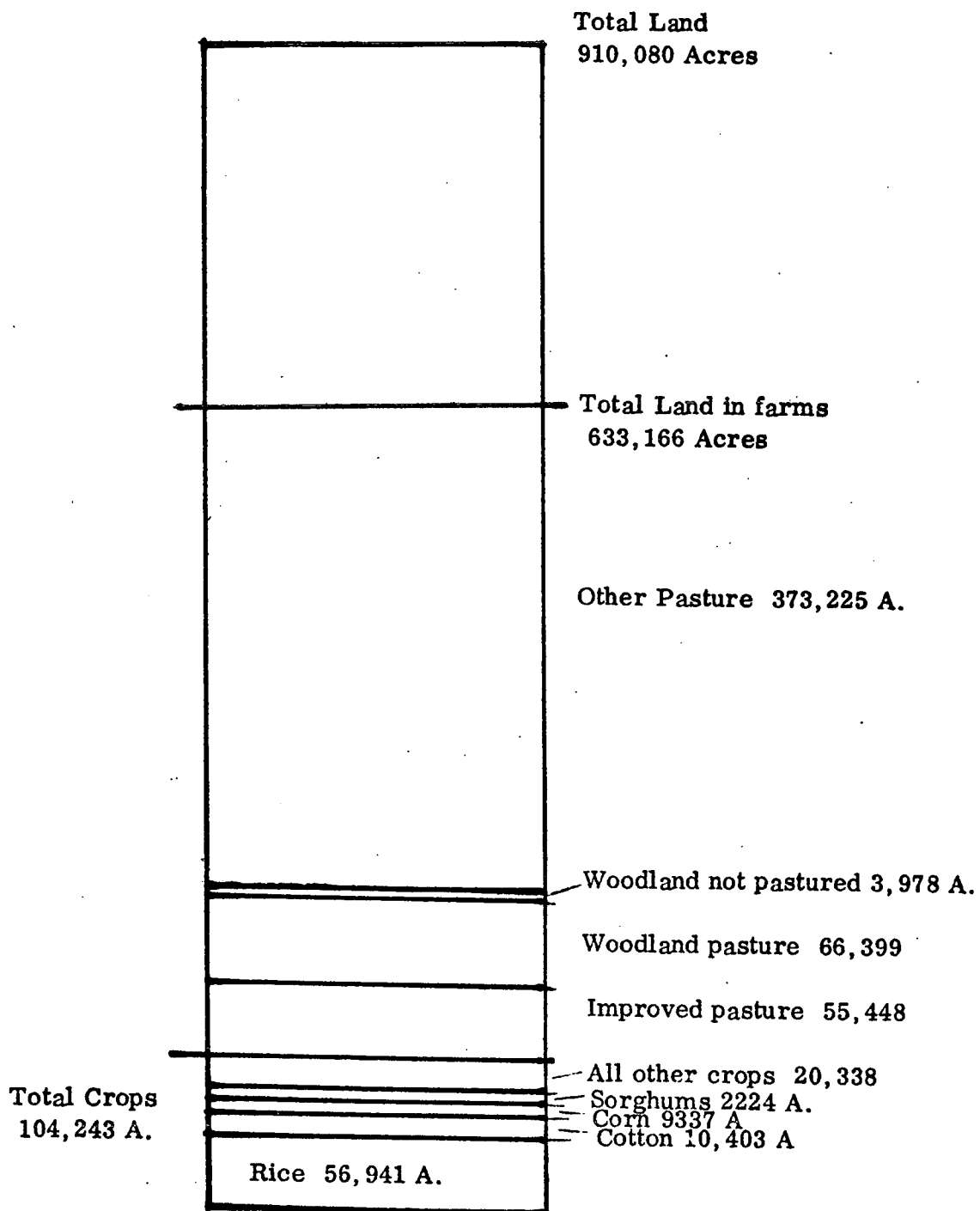
OTHER -- Urban lands devoted to uses other than agricultural in nature.

In 1971 the land use of Brazoria County was as shown in Figure 1.

F. FLOOD PROBLEMS

The Brazos River and Chocolate Bayou are subject to frequent flooding. The greatest flood known to have occurred on Chocolate Bayou during the past 35 or more years occurred on July 14, 1939. The level at Alvin was 30.2 feet above mean sea level. According to residents in

FIGURE 1
BRAZORIA COUNTY LAND USE*



*"Long Range Brazoria County Program" Prepared by Brazoria Co. Program Committee, Brazoria Co., Texas, January 1971.

the watershed bridges then crossing the bayou were inundated by this flood. Figure 2 shows the regions adjoining Chocolate Bayou that are subject to flooding.

The highest flood level of the Brazos River ever recorded at East Columbia is 32.3 feet above mean sea level. This occurred on December 12, 1913. The regions adjoining the Brazos River that are subject to flooding are shown in Figure 3. Other low areas in the county which have tendency to flood are shown in Figure 3, also.

A flood plain is defined as "those areas subject to frequent periodic flooding and delineated as alluvial soils" by the Soil Conservation Service, U. S. Department of Agriculture. Although infrequent floods will exceed the limits of alluvial soils, these alluvial soils, which are water deposited soils, represent the areas most often inundated by flood waters and represent the most realistic flood plain.

The continuing expansion of residential, commercial and industrial development in the Chocolate Bayou flood plain will increase the importance of planning wisely for use of the flood plain. New construction such as paved streets, parking lots, building roofs and landscape grading will result in greater runoff and consequently raise flood heights along the bayou.

G. GENERAL CONSIDERATIONS AND CONSTRAINTS ON SITES

Selection of satisfactory sanitary landfill sites demands careful preliminary evaluation of local conditions. Landfills are designed to care for the disposal of all solid wastes. Where compacted refuse is placed in the fill to a depth of 6 feet, it is estimated that one acre of land per year will be required per 10,000 population.*

* "Municipal and Rural Sanitation," Sixth Edition, by V. M. Ehlers & E. W. Steel, McGraw-Hill Book Co., 1965.

FIGURE 2
FLOODING REGION OF CHOCOLATE BAYOU

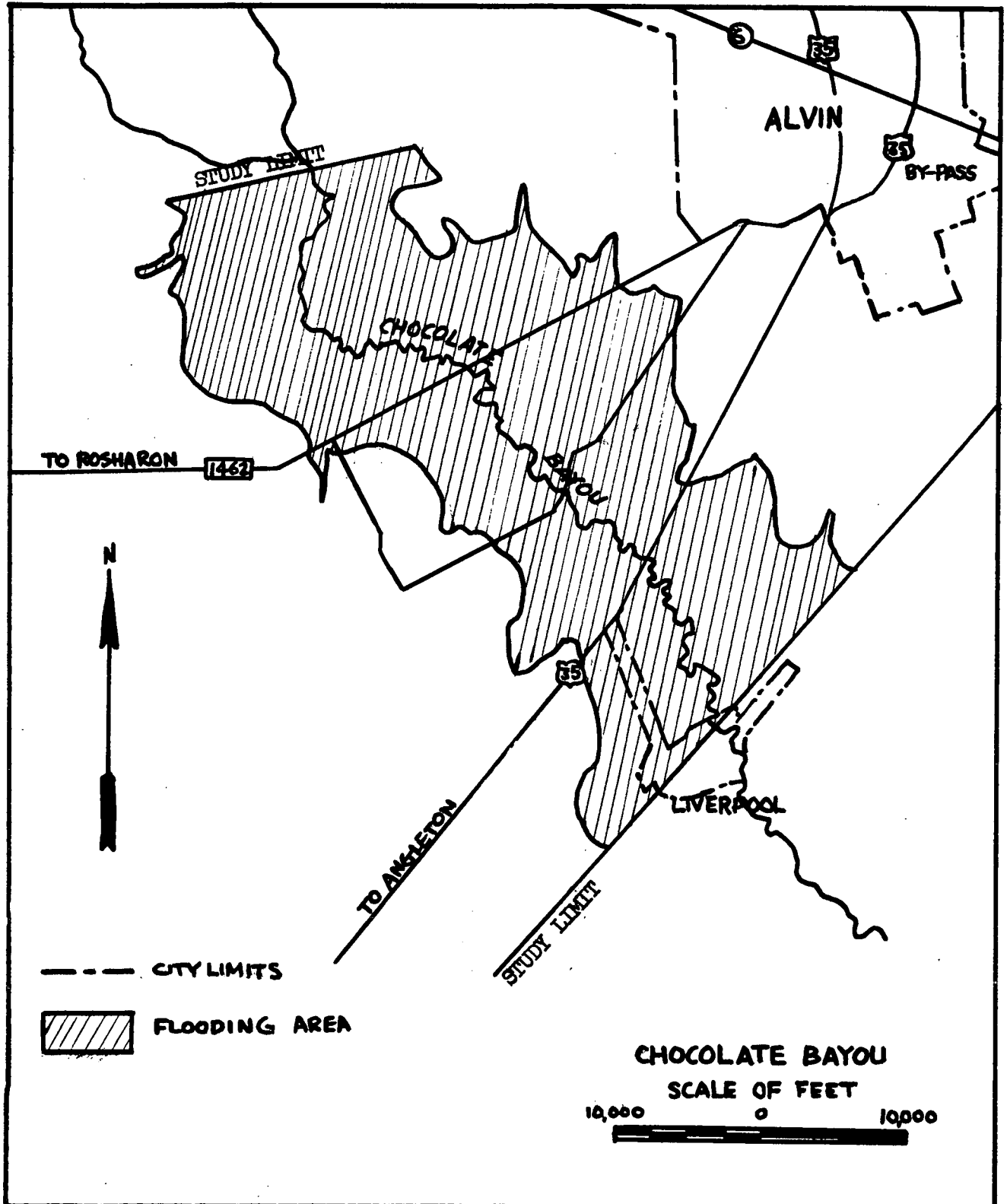
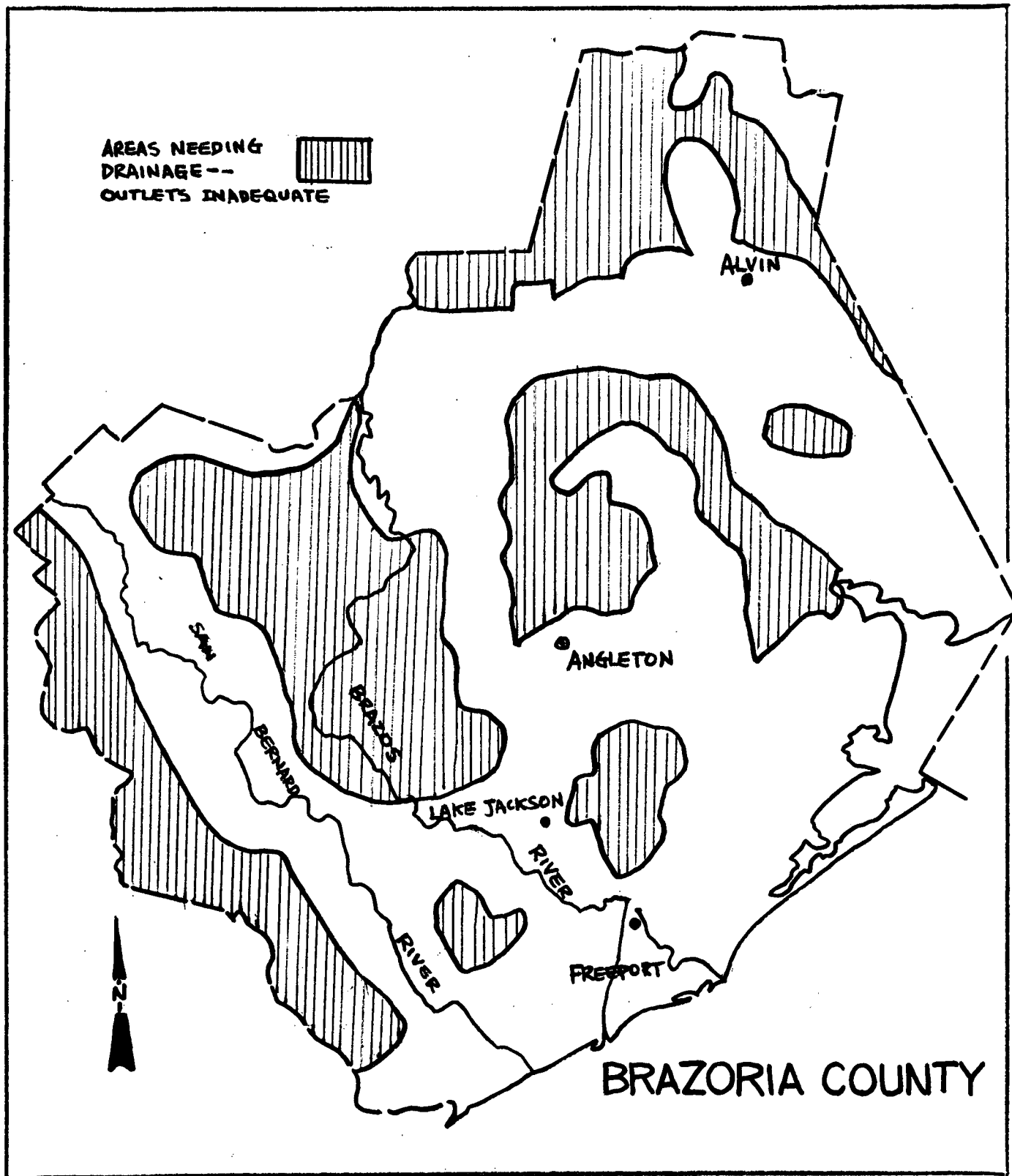


FIGURE 3

AREAS SUBJECT TO FLOODING BY BRAZOS RIVER



REFERENCES FOR FIGURES 2 and 3

FOR FIGURE 2

1. "Flood Plain Information for Chocolate Bayou, Brazoria County, Texas," by Brazoria County Conservation and Reclamation District No. 3, Alvin, Texas, and The Texas Water Development Board, Austin, Texas, June 1971.

FOR FIGURE 3

1. "Sam Houston Resource Conservation and Development Project Application," USDA-SCS, No. 4-27128, Fort Worth, Texas, September 1968.
2. "The Report of the U. S. Study Commission (on Water Resources in) Texas," Part III, The Eight Basins, March 1962.

Table II shows the projected amount of solid waste and the area required for sanitary landfilling through 1990.

Prospective landfill sites should be evaluated with respect to types of soil available, drainage, prevailing winds, availability of access roads, and haul distance involved. Possible contamination of ground and surface water should be considered in choosing a site.

Brazoria County has shown a steady increase in population during the last seventy years. The number of families in the county increases due to the proximity of Brazoria County to Houston and increased industrialization and development in this county.

The "Long Range Brazoria County Program", prepared by the Brazoria County Program Committee, January, 1971, said that young people as well as adults throughout the county recognized the need for additional recreational opportunities.

So it would appear that one of the major long range improvement programs could be the use of completed landfill sites to provide more parks and recreation facilities for the communities.

H. USE OF AERIAL PHOTOGRAPHY

The photography used for this study was taken by NASA on mission No. 145, November 3, 1970. The format was 9 x 9 inch color positive transparencies at a scale of 1:120,000 and color IR positive transparencies at a scale of 1:60,000. Using this imagery details of urban growth patterns into adjacent rural countryside could be clearly seen. The size and shape of the cities and the cultural or man-made resources could be seen; this made possible studies of patterns between cities.

When working with aerial photographs it is useful to have maps

F

TABLE II

Population and Solid Waste Generated/10 Years.

Population Center	Population			Total Waste = W		Total Average = Acres/10 Yr.: 10,000 Pop.
	1970	1980	1990	1970-80 Population Average x 10 Ac.Ft./ Yr./10,000	1980-90 Population Average x 13 Ac.Ft./ Yr./10,000	
Alvin	10,671	15,500	25,000	13.08	19.8	21.8 33.1
Angleton	9,770	14,100	20,000	11.93	21.2	18.3 35.4
Freeport	11,997	25,000	50,000	18.50	48.8	30.8 81.5
Lake Jackson	13,376	25,000	30,000	19.19	35.8	32.2 59.8

Source:

"Population Projections" Gulf Coast Planning Legion, Houston - Galveston Area Council
April 1, 1972.

The Table shows total waste generation and sanitary landfilling area estimation for the requirement of 1970-80 and 1980 - 90.

available to provide an idea of the local relief and an accurate geodetic base for the preliminary site evaluations. Maps used in this study include:

- (1) U. S. G. S. topographic maps.
- (2) U. S. G. S. geological maps.
- (3) General Highway map of Brazoria County prepared by Texas State Highway Department
- (4) General Soil map of Brazoria County, prepared by Soil Conservation Service.
- (5) Detailed street maps of Alvin, Angleton, Freeport, and Lake Jackson.
- (6) U. S. G. S. well location maps (1" = 2 miles).
- (7) Environmental Geologic Atlas of the Texas Coastal Zone -- Galveston Area by W. L. Fisher, et al., Bureau of Economic Geology, U. of Texas, 1972.

Comparing the interpretative quality of the two kinds of photography it was found that:

- (1) For the interpretation of and detailed mapping of soils, natural color aerial photography was the most useful because of the greater number of distinguishable color tones present in the appearances of the soils and soil conditions.
- (2) The IR photography was considered better than the conventional color photography for variations in soil texture, composition, and moisture.
- (3) The chlorophyll reflectance allows IR photography to assist in the identification of cultivated land and for appraisal of road right-of-ways.

The detailed information concerning the photography of missions No. 145 and 191 is given in Chapter II.

I. ALVIN

Alvin, in the northeastern part of Brazoria County, is a prosperous city with a population of 10,671. Monsanto Chemical Company is near Alvin, adding to the economic development and growth of the city. Alvin is on Texas Highways FAP 35 and 6, and is bounded by Galveston County on the east. Chocolate Bayou meanders by in a southeasterly direction and drains an area of some 159 square miles before it empties into Chocolate Bay, and thence into west Galveston Bay. The watershed lies between the communities of Alvin and Angleton and its upper limits are a few miles south of the Houston city limits. On the north is the thriving town of Pearland about eight to ten miles west of the NASA Manned Spacecraft Center. The area has an abundance of oil and natural resources.

The obvious land available for sites would be to the northwest within a 6 mile haul distance, and some land to the wouthwest, south, and southeast. Notice in Figure 3 that if the landfill is too far from Alvin in the northwest and northeast that a potential flooding condition could exist.

Nine sites were selected for study. They are shown as white polygons with Roman numbers on the attached aerial photograph of the Alvin vicinity.

(a) Site 1. East of South Texas Water Company canal, south of F.M. 1462, west of Chocolate Bayou, north of FAP 35; the site is a short distance north from the corner of Parker Road. This site has a haul distance of about 7 miles. All of the others are 6 miles or less.

(b) Site 2. South of Davis Bend Road, east of Chocolate Bayou,

north of F.M. 1462.

(c) Site 3. East of Chocolate Bayou, southeast of FAP 35, southwest of Highway 2917 and Stringtown Road.

(d) Site 4. South of Briscoe Canal, east of Missouri-Pacific Railroad; the site is along the FAS Highway which extends from Houston Street. This site is bounded by a canal on its southeast side.

(e) Site 5 and Site 6. East of Mustang Bayou, west of county boundary between Galveston and Brazoria County. Site 5 is on the west side of the Missouri-Pacific Railroad while Site 6 is on the east side of the railroad.

(f) Site 7. North on Highway 6, south of Mustang Bayou; this site is about 4 miles from the city center toward the northwest.

(g) Site 8. North of Mustang Bayou, south of Chigger Creek; the site is at the corner of a small county road.

(h) Site 9. Three-quarters of a mile north of Highway 6; the site is alongside Mustang Bayou and at the end of a small county road.

Table III shows the numerical values for the nine potential sites selected for study around Alvin.

TABLE III
MATRIX RATING SYSTEM FOR LANDFILL SITES
ALVIN, TEXAS

Criteria	Sites								
	1	2	3	4	5	6	7	8	9
Land Use	0	0	0	0	0	0	0	0	0
Drainage	5	5	8	8	8	8	5	10	10
Soil Type	10	5	10	4	Not Available		4	0	0
Road Surface	3	5	0	2	3	0	0	5	5
Accessibility	0	3	0	0	0	0	0	3	0
Totals	18	18	18	14			9	18	15
Area of Site (acres)	75	50	65	85	50	50	50	40	50
Elevation (feet)	35	25	35	28	35	35	50	35	35
Area Needed	1970-80 21.8 Acres								
Area Needed	1980-90 <u>33.1 Acres</u>								
	Total 54.9 Acres								

J. ANGLETON

Angleton, the county seat of Brazoria County, has a population of 9,770. Angleton has continued to prosper as a center for agriculture, and for oil and gas activities.

The potential sites for Angleton, and the other cities in the county except Alvin, are not indicated on photographs. They are simply described by way of showing that the same procedures were used in studying them as was true of those sites pictured herein.

The potential sites for Angleton are as follows:

(a) Site 1. At the corner of FAP 288; site which is between FAP 288 and old Airland Road. The site is approximately where FAP 288 crosses the first lateral road from Angleton, almost 6 miles from the city.

(b) Sites 2, 3, 4. South of the city of Danbury and the Missouri Pacific Railroad, east of Flores Bayou, west of Austin Bayou, each six miles from the center of Angleton. These may be further described: Site 2 is north of Eagle Gully, Site 3 is east of Eagle Gully, and Site 4 is west of Eagle Gully

(c) Sites 5 and 6. North of FM 2004, west of Brushy Bayou, south of King Road, northwest of McCormack Reservoir. The sites are about a mile apart in a northeast-southwest direction.

Table IV shows the numerical values for the six potential sites selected for study around Angleton.

TABLE IV
MATRIX RATING SYSTEM FOR LANDFILL SITES
ANGLETON, TEXAS

Criteria	Sites					
	1	2	3	4	5	6
Land Use	0	0	0	0	0	0
Drainage	8	8	8	8	8	8
Soil Type	5	3	5	10	5	10
Road Surface	0	3	5	5	3	3
Accessibility	0	0	0	0	0	0
Totals	13	14	18	23	16	21
Area of Site	50	75	30	25	80	50
Area Needed	1970-80		18.3 Acres			
Area Needed	1980-90		<u>35.4</u> Acres			
	Total		54.9 Acres			

K. LAKE JACKSON

This city was planned by Dow Chemical Company to serve as home sites for their employees. The population is 13,376. Lake Jackson is thought by many to be one of the most attractive cities in the state. The Dow-Lake Jackson Airport is located northwest of the city. While the haul radius for Alvin and Angleton was taken to be six miles, eight miles was deemed to be more workable for Lake Jackson.

The potential sites for this city are:

- (a) Site 1. South of Little Slough, north of Big Slough, west of F.M. 523.
- (b) Site 2. East of F.M. 2004, northeast of the city center, and about $1\frac{1}{2}$ miles northwest of Site 1.
- (c) Site 3. Northwest of Brazoria County Airport, south of Highway 332; this site is some distance from the end of F.M. 2004.
- (d) Site 4. East of FAP 288, north of Little Slough; the site is adjacent to woodland and is about a mile south of Site 2.

Table V shows the numerical values for the four potential sites selected for study around Lake Jackson.

TABLE V
MATRIX RATING SYSTEM FOR LANDFILL SITES
LAKE JACKSON, TEXAS

Criteria	Sites			
	1	2	3	4
Land Use	0	0	0	0
Drainage	8	5	5	8
Soil Type	10	10	10	10
Road Surface	3	3	3	10
Accessibility	0	0	0	3
Totals	21	18	18	31
Area of Site	80	65	60	40
Elevation (feet)	10	10	15	10
Area Needed	1970-80	32.2 Acres		
Area Needed	1980-90	<u>59.8</u> Acres		
	Total	92.0 Acres		

L. FREEPORT

The Dow Chemical Company located its first plant in Freeport in 1944. The city has grown continuously since then and now has a population of 11,997. Freeport is sometimes called the "Shrimp Capital" of the world. It has a fine harbor for deep water vessels, and is served by the Intracoastal Canal.

An 8 mile haul radius was used for the analysis of sites. The potential sites for Freeport were all selected to the west of the city and are as follows:

- (a) Sites 1 and 2. South of Highway 36, west of the Brazos River; further, Site 1 is on the west side of the road, and Site 2 is on the east side of the road. These two sites have a very short haul distance, approximately 2 miles, and are adjoining locations.
- (b) Site 3. North of Highway 36, west of Hanley Road, about $3\frac{1}{2}$ - 4 miles west of the city center.
- (c) Site 4. Along the east side of Jones Creek; the site is north from the corner of Frontier Lane and S. F. Austin Road, about 5 miles from the city center.

Table VI shows the numerical values for the four potential sites selected for study near Freeport.

TABLE VI
MATRIX RATING SYSTEM FOR LANDFILL SITES
FREEPORT, TEXAS

Criteria	Sites			
	1	2	3	4
Land Use	0	0	0	0
Drainage	5	5	2	8
Soil Type	10	10	10	10
Road Surface	5	5	0	5
Accessibility	3	3	0	3
Totals	23	23	12	26
Area of Site	40	35	45	75
Elevation (feet)	5	5	8	10
Area Needed	1970-80	30.8 Acres		
Area Needed	1980-90	<u>81.5</u> Acres		
	Total	112.3 Acres		

M. FINAL RECOMMENDATIONS

Freeport, Lake Jackson and Angleton are relatively close together and therefore might find mutual benefit in developing a regional plan for solid waste disposal. Combined planning and management should have the effect of lowering somewhat the costs involved in finding, preparing, and maintaining suitable sites, and in reducing operating expenses connected with purchase and repair of equipment.

The potential advantages of regional planning for solid waste disposal are:

- (1) economy of large-scale operation
- (2) more responsive and effective administration
- (3) uniform standards of operation over the region
- (4) development of a consistent regional disposal policy, and this is a benefit to private collectors.
- (5) long-term plans can be developed.

The two potential disadvantages which quickly come to mind are:

- (1) local autonomy is surrendered to a regional controlling agency
- (2) communities with better equipment and procedures are combined with communities which may not be so well managed and equipped.

As this immediate Gulf Coast Area becomes more populated and urbanized it would seem that the advantages of planned uniform regional waste handling procedures would out-weigh the disadvantages to such an approach.

All this notwithstanding, the cities of Brazoria County were studied separately and the recommendations for each city are given

separately.

For Alvin Site 7 has the lowest score in the matrix rating table. The soil types, Edna clay loam and Edna fine sandy loam, are an advantage for this site. The only disadvantage is that the site is close to the Highway 6 and would require screening. The land valuation could be high also because of the highway. Site 4 is the second recommended location. It is pasture land. The soil type is Edna-Waller complex. The road surface to the site probably would need improving before the sanitary landfilling operation begins. Because only 54.9 acres of land will be needed through 1990, the two sites, namely 7 and 4, are enough to satisfy the requirement.

The recommended location for Angleton is Site 2. Although Site 1 is ranked one point less than Site 2, the former is considered to be too close to Highway 288. The cost of acquiring this property would most likely be more than that for Site 2. Actually the real decision between the two should be made after a more detailed analysis. Site 2 can satisfy the area needed through 1990.

All of the sites selected for Lake Jackson have only one soil type -- Pledger clay. Generally, clay is not desirable for cover material because of its poor workability. The area needed through 1990 is approximately 92.0 acres. It is recommended to use the two sites with the lowest ratings, namely, Sites 2 and 3, to meet the requirements. They are within the 8 mile haul radius from the city center.

The soils of the Freeport sites are all clays of various categories. The landfill area needed through 1990 is 112.3 acres.

This requirement could be met using the three sites 1, 2, and 3.

Because of the disadvantage of clay to sanitary landfilling operations further study to find more suitable cover material should be undertaken and plans for site preparation and operation should be made before finally selecting the sanitary landfill location.



ALVIN, BRAZORIA CO.

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CASE STUDY OF FORT BEND COUNTY

Fort Bend County is located in the generally level Coastal Plain of Southeast Texas with an area of 862 square miles. This county is adjacent to the Houston metropolitan area. The shortest distance of separation is on its northeastern border and is only five miles. It is bordered by five counties, namely, Harris, Waller, Austin, Wharton and Brazoria counties. The distance from its southern border to the Gulf of Mexico is 35 miles. Brazoria County separates Fort Bend County from the Gulf.

The Brazos River, a major river of Texas, passes through the county. Its flood plains are fertile and well suited to most crops except rice. Most of the forest areas of the county are in the southern part of the county. Many oil fields are situated there, too. The San Bernard River, the second largest river in the county, flows on the western border of the county forming a natural border line with Wharton County on the west. The San Bernard river also contributes considerable forests and agriculture lands. The tributaries of both rivers are widely distributed within the county. They constitute in large measure the natural resources upon which the agriculture of the county has been developed.

This county has a good climate suitable for a long growing season and favorable for developing pasture lands for the livestock industry. The summers are hot and dry; winters are

short and mild⁽¹⁾. The annual rainfall is 45.1 inches, and the annual mean temperature is 69.2°F⁽²⁾. Rainfall is fairly evenly distributed throughout the year. Hurricanes from the Gulf of Mexico occasionally reach the county in the summer and fall. They bring winds and torrential rain that damages the crops. The prevailing wind directions of the county are from the south and southeast but in the period from October through January the winds are from the north^(3, 4).

Since this county is adjacent to the greater Houston metropolitan area, the ground transportation network is well developed. The federal highway US-59 extends across the county from northeast to southwest. It has been converted to a free-way type highway from the northeast border to the central part of the county. US-59 passes through the two major cities of the county. Both the highway and railway networks radiate from the twin cities of Richmond and Rosenberg, which are located almost in the center of the county.

According to census records and the predictions made by the Houston-Galveston Area Council, the three cities of Richmond, Rosenberg and Sugarland, are the largest cities in the county⁽⁵⁾. However, the communities of Stafford and Missouri City will undoubtedly develop very rapidly within the next twenty years. They are located between the three major cities of the county and Houston. Thus, these five cities may certainly be considered the major urban areas to be dealt with in studying the solid waste disposal problem.

From studying aerial photographs, the general highway map, and the proposed community planning information for Fort Bend County, several characteristics are revealed regarding the development of these five cities. Richmond and Rosenberg are very closely situated and tend to join to form a combined city. Missouri City, Stafford and Sugarland, on the other hand, are becoming increasingly linked together as they urbanize so that they will form a city belt on the eastern side of the county. The circles formed from the refuse hauling radii of the different cities overlap, thus, it was deemed wiser to consider the potential sites for landfilling within the overlapped areas for the corresponding cities in a planned joint program than to independently consider each individual city. Thus, the site selections, as discussed herein, will deal with the study for two separate city groups.

The population projections and the required areas for sanitary landfilling for each city group are listed in Table I⁽⁵⁾.

The soil associations of this county are classified into four main patterns: Lake Charles - Bernard soils; Edna - Bernard soils; Katy - Waller soils and Miller-Norwood-Pledger soils. The first three patterns are soils of upland, and the last pattern consists of soils characteristic of the flood plains⁽¹⁾. The flood soils of the Brazos River cover very wide areas on the east side of the river bank. Less than ten percent of the flooded soils of the county lie along the banks

Table I. Population Projection and Landfilling Area Required for Fort Bend County.

City	Population (P)			Volume of Waste (W)		Total Acreage $W \times \frac{1}{6ft} \times 10 \text{ yr.}$	
	1970	1980	1990	Pave. x 10 ac.ft. /yr/10,000	Pave. x 13 ac.ft. /yr/10,000	'70-'80	'80-'90
Missouri City	963	2,500	9,500				
	2,845	6,000	20,500				
	3,318	7,000	15,000				
Total	7,126	15,500	45,000	11.3	39.3	18.8	65.5
Richmond	5,777	10,000	20,000				
Rosenberg	12,098	18,000	30,000				
Total	17,875	28,000	50,000	22.9	50.7	38.2	84.5

of the San Bernard River. The parent materials of the soils in this county are generally divided into three formations: Lissie, Beaumont, and Alluvial soil. The Lissie formation consists of soils ranging from sands to sandy clays. The Beaumont formation consists mainly of clayey soils. This formation is found principally in the area between the rivers. The Alluvial formation consists of deposits of calcareous materials from the sediments of the Brazos watershed. The drainage areas of other streams are entirely in the Coastal Prairie and are comprised of soils of the Kaufman and Iuka series. The drainage slope in this county ranges from level to very gently sloping. As already stated, there is a wide area composed of flooded soils in the county.

I. The City Group of Richmond - Rosenberg.

A. General Description.

The cities of Richmond and Rosenberg are located in the central part of the county. They are close together, and their urban developments must of necessity inter-relate. Sometimes they are referred to as twin cities. The Brazos River passes along their northern side and forms the northern city limit of Rosenberg. The river bends and bisects the eastern part of Richmond. Richmond is the seat of this county and Rosenberg is the most populated city of the county.

The federal highways US-59 and alternate US-90 come

together in a line to pass through these two cities. State Highway 36 passes through this urban area, generally in a north-south direction, although all three major highways radiate equally from the western side of Rosenberg. On the western side of Rosenberg the three railways are distributed in the same way as the highways. Going east, a railway is parallel to Highway 90A which leads into Houston. This combined urban area may certainly be considered the center of the transportation network of the county.

Ranches, farm lands and pastures surround this urban area. One small spot of young trees is located near the northern part of Richmond. The ground elevation is around 95 feet to 100 feet above sea level. When the freeway construction on highway 59 is completed in the near future, the community development and residential expansion should really be significant, especially in the southern portion of Rosenberg.

B. Sanitary Landfill Site Selection Constraints.

Topographically, the Brazos River forms a boundary on the northern side of the two cities, therefore the selection of potential sites for sanitary landfilling should take into account the location of bridges which pass over that river. There are only two places where bridges connect the banks of the river. One bridge is on the northern side of Rosenberg; the other is located

in the eastern part of Richmond.

The northern side of the Brazos River in this vicinity is primarily a flood plain. State Prison Farm land constitutes a considerable amount of the land located inside the proposed hauling circle of this urban area. Both of the land areas just mentioned were excluded from the study of potential landfill sites.

The favorable locations for selection are on the southern side of the Brazos River. Land which appears to be planned for city development, land which is adjacent to the new freeway, large areas of cultivated land, and industrial sites should be avoided in the search for land to use for sanitary landfilling. The pasture lands seem to offer the most feasible locations.

Three locations were selected. These are discussed in the following paragraphs.

C. Potential Landfill Sites:

The radii of refuse hauling distance for the cities of Richmond and Rosenberg were taken to be 6 miles and 8 miles, respectively. The circle for Richmond is almost entirely enclosed within the circle for Rosenberg. The nearness of the two cities can be seen on the attached Fort Bend County photograph. The required landfill area to meet the estimate of solid waste for 1990 is 122.7 acres.

a. Site 1:

This site is located near the northern edge of Richmond and has an area of 124 acres. The distances to this site from the assumed centers of waste production for Richmond and Rosenberg are 1.5 miles and 4.3 miles, respectively. The ground elevation is about 90 feet above sea level and exceeds the possible flood stage in the immediate area. The Brazos River is about 700 feet from the northern side of the site. There are forests on both the northern and the southern sides of the site. These could form good wind shields for the landfilling operation.

The area is totally covered with Yahola fine sandy loam⁽¹⁾. This material should be quite suitable for covering each layer of refuse in the landfill. A house is located on the southern side of the site about 1400 feet away. There are no other buildings or wells in the vicinity.

The possible hauling route could be along Avenue H of Rosenberg and Jackson Street of Richmond (both coincide with highway 59), via Collins Road to the north, then left on Pultar Road, continuing in a northward direction on a county road to reach the site.

b. Site 2:

The location of this site is south of Richmond and to the southeast of Rosenberg. The distance from each city is about 5 miles. The northern edge of the site is bounded by the dry creek leading to Lake George. On the southern side, there is an irrigation ditch. Farm-to-Market road No. 2977 is not far away from the western edge. On the north-eastern side there is a county road.

This site is uncultivated land. There are no forests or buildings in the vicinity. The soil type is Edna fine sandy loam. On the photography four small spots of wet land (may be ponds) were identified within this area. Some of these may be small moist recently cultivated spots. The water table around these spots must be relatively high.

Farm-to-Market road No. 762 is the main route which connects to both cities where the solid waste will be generated. The small Farm-to-Market road No. 2977 goes from the aforementioned road to the site. - An oil field is located about 1.2 miles away on the southern side of the site. The county roads surrounding the site appear to be more or less for access to the oil fields.

The area of this site is 150 acres. This is large enough to satisfy the space requirement for

solid wastes from this twin city area through 1990.

c. Site 3:

This site is located on the northern side of Richmond. The State Prison Farm has a property line which stretches along the eastern side of the area. On the western side of the site a county road extends from farm road 359 by a distance of 2,000 feet. The only way to haul refuse to this site is via highway US-59 and across the Brazos River at the bridge on the eastern side of Richmond. Consequently, the actual distance from Rosenberg to the proposed site is 7.5 miles.

This site is pasture land while most of the surrounding property is cultivated land. A few farm houses are located on the southern and northwestern sides of the area. Domestic water wells are probably located in this dwelling area. Since these people live close to the site, the possibility of water contamination and social objection to the sanitary landfill should be carefully investigated.

The soils of this site are composed of 60 percent Miller clay, 25 percent Miller silty loam and silty clay loam, and about 15 percent Alluvial Norwood clay⁽¹⁾. The ground elevation is about 80 feet above sea level. It is situated between the Brazos River and Oyster Creek. The possibility of

flooding does exist. The highest flood stage ever recorded in the vicinity is 89 feet above sea level. Since the elevation of the site is not higher than that of the surroundings, and since Oyster Creek and another small stream are close to the site, the underground water content, as expected, is relatively high.

D. Matrix Rating Table.

Table II shows the numerical values of the three sites evaluated regarding their use as sanitary landfills.

E. Final Recommendation.

Site No. 1 has the most favorable point score of the three sites within the proposed hauling range. Besides the general aspects of the site described before, this site undoubtedly has prominent value for other community development. If used as a landfill and completed this site could be converted into some kind of recreational area such as an athletic field, a playground for a school, or a park or golf course.

Water contamination from leachate or odors due to sanitary landfill operations in this area could cause problems.

Proper environmental engineering protection would have to be emphasized in the landfill operation. The site is close to the Brazos River, therefore a well

Table II. Matrix Rating System for Site Selection.Richmond and Rosenberg; Fort Bend County

Rating Item	Proposed Site		
	1	2	3
Land-Use	0	0	0
Drainage	0	8	5
Soil Type	0	0	5
Road Surface	5	0	0
Accessibility	0	0	0
Total Rate	5	8	10
Area (acre)	124	150	125
Estimated Area Required (acre)	1970 - 1980: 38.2 1980 - 1990: 84.5		
	$\Sigma = 122.7$		

compacted layer of clay ought to be put into the basin of the landfill to seal it. Consideration might be given to a dike for protection against high water.

The existing county road could be used as the landfill access road if it were improved to become an all-weather topped road. The additional operational costs resulting from these precautions would be offset by the future land-value, the initially low cost of land and the saving due to hauling refuse such a short distance.

The southern side of the site is protected by a forest, which is an excellent barrier to block pieces of paper and other trash from flying in the southern direction. A belt of forest at the northern side of the site (that is located along the southern bank of the Brazos River) could be utilized for reducing the wind force intensity and its effect on the landfill operation. Good management of a sanitary landfill operation at this site would accentuate the correctness of the selection of this site.

II. The City Group of Missouri City, Stafford and Sugarland.

A. General Description.

Missouri City and the city of Stafford are near the northeastern edge of the county and essentially join one another. The new residential developments and industrial expansion of metropolitan Houston have apparently reached

C²

this combination of cities. The city of Stafford will likely become a significant business area along highway 90A and between it and highway 59. Many communities of new-style residential houses are being built in this vicinity. Missouri City has primarily developed into a residential city and will likely have major growth extending in a southern direction.

Sugarland is located on the western side of Stafford about 8 miles east of Richmond. A sugar refinery, once the largest such factory in the world, is located at the center of the city. It constitutes the major industry of this city. The city is generally divided into two districts by highway 59 and the parallel railway. The northern portion is an industrial area, and the south is a very attractive residential district with several small lakes scattered among the dwellings.

Highway 90A and the parallel railway pass through the city centers of these three cities in an east-west direction. Highway 59 intersects highway 90A near the middle of this area and generally keeps the same route as highway 90A until reaching Rosenberg. A new route for highway 59 is being developed to extend into the center part of the county. It is expected to be finished within about two years. These transportation arteries are playing a key role of development of these cities. The proximity to the Greater Houston Metropolitan area is

causing a booming of real estate values and rapid urban development in these cities. The network of highways is relatively well developed in Fort Bend County.

The rate of influx of population in the cities of Stafford and Missouri City is unusual. The increase of people in the area from 1980 to 1990 is expected to be 240 percent for Stafford and 280 percent for Missouri City (see Table I). They exceed greatly the rate of growth considered to be the normal rate for the area (e.g., for the city of Richmond the percentage is 100 percent). Actually, from studying photographs of this area and in view of the current developments in Houston on the southwestern side, these large increases in population seem justified for these cities within the next twenty years. The solid waste disposal problem, therefore, will become more significant year by year. Proper planning for location of future sanitary landfill sites will soon be a matter of urgent public concern.

B. Sanitary Landfill Site Selection Constraints.

In this grouping of cities, it is helpful to consider the city of Sugarland as an independent unit and the combination of the cities of Stafford and Missouri City as the other unit. The recommended hauling circles for both units are 6 miles in radius. It is probable that the northeastern segment of each unit can not be used for locating sites since it extends into Harris

County. Incidentally, these same areas are becoming the new suburban communities of Houston.

There is an overlapping segment of the circles for both units. Beside this segment, the remaining segments have similar constraints for selecting individual sanitary landfill sites. The State Prison Farm west of Sugarland and the Central Prison Farm southwest of Sugarland occupy large areas of the non-overlapped segment of this unit. The most active direction of community planning for Missouri City, on the other hand, lies in the non-overlapped part of the circle of that unit and thwarts the location of potential sanitary landfill sites to the south of the city, thus the overlapping region of the two 6 mile radii circles, namely, the region bounded approximately by highway 6 on the west, a north-south line through Missouri City on the east, and the Brazos River on the south (encompassing the three cities) appears to be the appropriate area for locating the potential landfill sites. However, these three cities should be considered as one area of generation for solid wastes. The Central Prison Farm southwest of Sugarland and the areas planned for development in the interested cities are firmly linked together except for an unconfined area on the southern side. The new highway 59 and highway 6 contribute some of the constraint to the site selection problem.

The related population data and required areas for depositing solid waste are listed in Table I. The descriptions of the potential sites will be put into the following paragraphs.

C. Potential Landfill Sites:

a. Site 1:

This site is located to the south of the three cities as well as on the south side of highway 6 a short distance west of Oyster Creek. The site is marked "I" and is shown on the right hand side of the Fort Bend County aerial photograph.

Four buildings are just beyond the northern side of the site by a distance of about 400 yards. A small stream is also on the northern side. It flows along the roadside of highway 6 and water is accumulated into a narrow belt-type lake on the southeastern side of the site about 500 feet away. An intermittent stream passes through the site from north-west to south-east. For a short distance a dry stream also passes alongside the southwestern corner. The land is fairly flat but a slight depression exists near the western edge.

The major soil type of the site is the Miller Association; that is, about two-thirds of the area is Miller clay; one-fourth is silty clay loam; and the remainder is Miller silt loam⁽¹⁾. The charac-

teristics of the soil in this area are not the most suitable for using as cover material for a landfill operation. The clay proportion is high enough to make workability of the soil a matter of concern.

The possible haul routes are as follows: (1) For Sugarland, go southward on Dam Road, then use highway 6 to reach the site. (2) For Stafford and Missouri City, go south on Lester Road to the junction with highway 6, then turn west to the site. A short access road would have to be built at the northeastern corner of the site to connect with highway 6.

The rating values for sites and projected area requirements for the cities are listed in Table III.

b. Site 2:

This site is located in the same southerly direction from Sugarland and Stafford as Site 1 and is situated directly west of Site 1 by a distance of about one mile. It is on the south side of highway 6.

The site is a relatively narrow rectangular shape with its long sides in the east-west direction. There is a liberal scattering of small trees within the proposed area. It is presently used as grazing land. There are two strips of forest on its northern

and southern sides. The trees in these strips appear larger and are densely distributed. They would constitute good shields for protecting the proposed site in these directions.

The soil of the site is indicated to be Miller clay over about four-fifths of the total area. The remainder of the soil which is Norwood silty clay loam is located in the eastern side of the site⁽¹⁾. The overlapping area of the two 6 mile radius circles, that is, the area in which sites are to be located, was geologically formed by Alluvial deposits made by the Brazos River. The silty clay loam of the proposed site would be reasonably suitable for cover material for a landfill.

The distances to the cities from which the solid waste would come are 3.5 miles for Sugarland and 4.5 miles for the combination of Stafford and Missouri City. The same route from Sugarland as for Site 1 would be used except for turning south from highway 6 at Oil-Field Road to reach the site. For the other two cities, the suggested route would be using Blair Road and turning left to get on the Oil-Field Road. There is a little used road about 400 yards long which links the proposed site with Oil-Field Road.

A small stream is on the northern side of the site with the nearest separation being about 300 yards. There are no buildings or wells in the vicinity of the site. Cultivated lands surround the site just beyond the boundary forest strips.

D. Matrix Rating Table.

Table III shows the general rating values of the potential sites as just set forth in the narrative.

E. Final Recommendation.

The overlapping area of the two circles, as far as economical consideration is concerned, has large potential with respect to selecting a landfill site. Unfortunately about half of the overlap region is already within the planned and existing land use area. The constraints, as described in the preceding section, narrow the potential area to the southern part of this overlap region. The presence of Oyster Creek, the proximity of highways, and many cultivated fields, limit the lands available to be used as suitable sanitary landfill sites. Two sites were selected to show that there are still remaining suitable locations, even with the constraints.

Site 2 has the lower total rating as shown in Table III, and therefore, is suggested as the more suitable landfill site.

Table III. Matrix Rating System for Site Selection.Sugarland, Missouri City and Stafford,Fort Bend County.

Rating Item	Proposed Site	
	1	2
Land-Use	0	0
Drainage	8	0
Soil Type	5	5
Road Surface	0	3
Accessibility	3	3
Total Rate	16	11
Area (acre)	111.0	86.0
Estimated Area Required (acre)	1970-1980: 18.8 } $\Sigma = 84.3$ 1980-1990: 65.5 }	

The cost of cutting away the trees to make Site 2 ready for landfill operation would not seem to be great. The land is not really in use now, and could be purchased at a lower price than would be possible later after urban development begins nearby. The land cost saving would offset the tree removal. The future expansion of these cities is predicted to be large and extensive. Speculation in the real estate near the cities is expected to occur. There will be need for the residents in the area to find proper places for parks and recreation. The proposed landfill site could be converted into recreational space after having served as a disposal site. The trees on both sides would serve usefully whether the site was a landfill or a park.

References

1. "Soil Survey, Fort Bend County, Texas," U.S. Dept. of Agriculture, Soil Conservation Service, 1960.
2. "Ground-water Resources of Fort Bend County, Texas," Texas Water Development Board, Report 155, August 1972.
3. "Texas Almanac -- 1972~1973," The Dallas Morning News.
4. "The Handbook of Texas," The Texas State Historical Association, 1952.
5. "Population Projections, 1970-2020 for the Gulf Coast Planning Region," Houston-Galveston Area Council, April 1, 1972.



FORT BEND CO.

100-1

CASE STUDY OF LIBERTY COUNTY

Liberty County is located at the eastern side of the HATS area. Generally, it is in the southeastern part of Texas on the Western Gulf Coastal Plain. It has an area of 1,173 square miles(1). It is surrounded by the following counties in the HATS area: San Jacinto County on the north, Montgomery and Harris Counties on the western border and Chambers County on the south.

The Trinity River flows through the central part of the county in a north-south direction. Because of the river, there are considerable marshlands with dense forests on both sides of the river. The width of this area ranges from four to eight miles. In these marshy basins, the ground elevation is about 25 feet above sea level. These areas are relatively low compared to the other regions of this county. Oil resources are abundant in these marsh zones or in the adjacent areas. Approximately 70% of the county area is wooded land with pine, oak, ash, hickory, cypress and walnut being the major kinds of trees(2). Marshy swamps are about 20% of the county and these are principally in the southern part of the county.

The topographical features range from a high in the northern portion with an elevation of about 180 feet near the city of Cleveland down to an elevation of 25 feet around the swampy areas in the south.

Trinity River and its tributaries comprise the major water resources of the county. Rice production is the principal form of agriculture in the county. The East Fork of the San Jacinto River comprises the

chief natural resource of the western part of the county. Cedar Bayou runs along the southwestern boundary and has a minor influence on the county.

The annual rainfall is 51.2 inches. This is relatively higher than that of the other counties sharing its border; the only one close to this intensity is Chambers County(1). The weather is fairly warm and humid because of the high precipitation and relatively low evaporation due to the dense forests. The annual mean temperature is 69°F(2).

Federal Highways 59 and 90 are the two major roads for connecting the larger cities of the county with the other cities of the state of Texas. State Highways 146 and 321 serve to complete the major transportation network of this county.

The population records of Liberty County and of the two major cities -- Liberty and Cleveland, are shown in Table I.

Table I. Population of Liberty County(3)

Year County or City	1960	1970	1975	1980	1985	1990
Liberty Co.	31,595	33,014	38,000	52,000	63,000	79,000
Cleveland		5,627	7,000	9,000	10,000	12,500
Liberty		5,591	6,000	8,000	10,000	15,000

The case study for the selection of potential sanitary landfill sites for these two cities is reviewed in the succeeding paragraphs.

I. LIBERTY

A. General Description

The city of Liberty is located in the southern half of the

county. It is also surrounded by forests and underground there are rich resources of oil and gas. The Trinity River flows along the western side of Liberty, separated from the city by a distance of about one mile, on the average. The southwestern outskirts of the city extend almost to the river bank. The land around Liberty is an alluvial plain of the river. It is apparent from the color photographs that the areas just beyond the outskirts of the city are covered by alluvial soils.

The ground elevation of the city ranges from 15 feet to 25 feet with the slight downward slope toward the southern side.

Oil, gas, and timber are the major industries of this city. The South Liberty oil field occupies a wide area as large as that of the city of Liberty. This oil field is located at the southern side of the city and on the east bank of the Trinity River. Another large oil field is the South Dayton oil field, located opposite the South Liberty field on the west bank of the river. These fields produce much oil and gas, and support the urban development of this community.

Highway 90 is the major transportation artery, passing through the urban area in the southern side of the city. FM 146 and FM 563 extend from Liberty to the north and to the south, respectively. The Southern Pacific Railway is the only rail route serving this city.

B. Sanitary Landfill Site Selection Constraints.

The principal constraint for location of potential sites for sanitary landfills is caused by the Trinity River. Because of the proximity of the river to the urban area and the presence of forests near the city, there are relatively few prospective pieces

of land suitable for sanitary landfills. From both engineering and economical considerations, it seems desirable that the potential landfill site should be selected alongside farm roads rather than alongside major state highways. Therefore, the possibilities of locating a suitable site for Liberty would seem to be largely on the northeastern side of the city.

C. Potential Landfill Sites.

Six locations were selected for study as potential sanitary landfill sites. They are shown as white polygons marked with Roman numbers on the attached photograph. Corresponding to the 1990 estimate of population, the solid waste hauling radius for Liberty is 6 miles. In the following paragraphs the features of each site are discussed.

a. Site 1: This site is located on the northeastern side of the city and on the western side of road FM 1011. Ground elevation is about 25 feet above sea level. An origin of Palma Bayou, a tributary of the Trinity River, is on the western side of the site; a small hill is on the eastern side just beside the road FM 1011.

From the photography this is determined to be a marsh land with a large moisture content in the soil. The soil type is Kaufman clay, which has the characteristics of slow permeability and high shrink-swell behavior. Since it is a low-lying site and very close to the bayou, the possibility of flooding is inevitable. Care would have to be exercised to protect this site from flood water if it were chosen to serve as a landfill site.

The hauling distance is about 3 1/2 miles from downtown

Liberty. The route of hauling refuse would start on Main Street and go northward on Highway 146, then northward on FM 1011, and finally westward to reach the site.

The area of the proposed site is 55 acres. This is more than enough to cover the estimated requirement for 1990.

b. Site 2: This site is located in a good geological location. State Highway 146 passes on its southern side and is only a very short distance from the southeastern corner. Accessibility of the site is excellent. A new access road of less than 100 feet length would give a good outlet from the site to Highway 146.

The topographic character of this location indicates that it would be a suitable place for a sanitary landfill. The ground elevation is 50 feet above sea level. The surface slopes from the northwest corner down to the southeast corner. The northern side is bounded by dense forest and on both the western and southern sides rows of trees fence the location. It is a pasture land located about 4.8 miles from the center of Liberty. There are no streams or bayous along its boundaries. The underground water table is relatively low. Since ground deposits are Lake Charles clay and Vaiden clay, the groundwater contamination problem would be negligible. However the lack of cover material for the landfill will make the operational cost higher than that for a site in sandy loam. Consideration must be given to possible objections from residents who live in two houses nearby on Highway 146.

The hauling route would be simply to go north on Highway 146 from the northern side of the city to reach the site.

c. Site 3: This site is located inside a forested area about 4 miles from the city. It is remote from public roads so there would be need to provide an access road. There is an irrigation or drainage canal on the eastern side. The soil type is silty loam with some minor portions of the deposit being Vaiden clay. The water content of the soil is comparatively high. The area is 48.1 acres. The practical hauling route would be the same as that for Site 2, that is, to use Highway 146, but the route should turn to the right, passing along a small road part way and then along the proposed access road.

d. Site 4: This site is located on the northeast side of Liberty about 6 miles from the center of the city. FM 2830 is on its eastern edge and a county road passes along its southern side. Because of these two public roads, the accessibility of the site is very good.

This site is grazing land with a scattered woodland distributed over both the western and northern sides. An irrigation ditch on its northeastern corner extends in a northern direction. Because of a farmhouse near the southwest corner the possibility of environmental objections and contamination of a water well should be carefully considered.

The ground elevation is about 70 feet above sea level. The moisture content of the soil, which is identified as Morey silt loam, is thought to be low.

This site is near the perimeter of the hauling radius;

the distance makes the site marginal. The hauling route would be east on Highway 90 and FM 160, then left on FM 2830 to reach the site.

The area of this site is 30.3 acres. This is less than the required area by 6 acres. An adjustment of the solid waste depth in the landfill operation or extension of the site along its western side would satisfy the requirement.

e. Site 5: This site is located on the eastern side of Liberty, about 5 miles away. It can be reached by FM 160, which passes the site about 1,000 feet away on the southern side. A county road located on the eastern side of the site provides easy access. A dense forest on the northern side of the site could shield the landfill operation in this area.

This site is a pasture, with an area of 46.7 acres. This is enough area for landfilling to satisfy the 1990 estimate of need. The soil type is Beaumont clay and Morey silt loam. These occupy almost the same amount of area within the site. The few residents along FM 160 would be separated from the operation by the dense forest on the northern side of the site.

Since a county road is just on the eastern side of the site, the refuse trucks could easily reach the site. The hauling route would begin using Highway 90, turn to FM 160 to reach the county road and then turn to the right to enter the site.

f. Site 6: This site is located on the northern side of Liberty about a distance of 1 1/2 miles from the city's center. The nearest distance to the outskirts of the city is estimated

to be about 2,000 feet. The site is on a second terrace basin of the Trinity River. The ground surface soil is Cahaba fine sandy loam.

There are forests on the western side and a dirt road passes through the forest to join the county road on the west side. Ground elevation is about 15 feet above sea level. The site appears to be subject to infrequent flooding. Care would have to be taken to operate a landfill at this site and proper protection against flooding would be required.

This land is uncultivated; therefore, the cost to obtain it should be low. The location as a sanitary landfill for this city would be very convenient. A careful evaluation of the engineering and economic problems would have to be made prior to final selection. A new road would need to be constructed to replace the old dirt road which now serves as an access road.

The hauling route to this site is the shortest one of all six sites studied. Generally the main hauling route would be along North Travis Road, then turning right to reach the site.

D. Matrix Rating Table.

Table II shows the different evaluations for each site. Also, the measured areas and the required areas estimated for the year 1990 are listed.

Table II. Matrix Rating System for Site Selection.

Liberty, Liberty County.

Rating Item	Proposed Site					
	1	2	3	4	5	6
Land-Use	0	0	0	0	0	0
Drainage	10	5	8	8	2	8
Soil Type	10	10	5	5	5	0
Road Surface	3	0	10	3	3	10
Accessibility	0	0	3	0	0	3
Total Rate	23	15	26	16	10	21
Area (acres)	55	62.4	48.1	30.3	46.7	35.8
Estimated Area Needed (acres)	1970 - 1980: 11.3 1980 - 1990: 25.0 $\Sigma = 36.3$					

E. Final Recommendation.

Among the six selected sites, Site No. 5 is the most favorable location for a sanitary landfill site for the city of Liberty. This site is more or less pastureland, and is surrounded by cultivated lands on three sides. Its northern side is protected by a natural forest. This forest could serve as a screen to hide the landfill operation from the public as well as to eliminate any rejection on the part of the people living nearby.

By studying topographical maps and color photographs, this site is thought to be on a relatively high plain with an elevation

of 70 feet above sea level. This is the highest elevation around this vicinity. The Trinity River is on the opposite side of the city, separated by a distance of about 7 miles. Therefore, any danger of flooding appears to be negligible. Bayous or streams are approximately one mile away. The nearest water well is located on the northwestern corner about 1300 feet from the site boundary; therefore, the water contamination problem is negligible.

This site is remotely located from the city. The Magnolia Ridge Country Club golf course is on its western side about 2 1/2 miles away.

The site has a good shape and an access road is close to the edge of the site at its western side. There would appear to be no operational difficulties foreseen in using this location as a sanitary landfill site.

II. CLEVELAND

A. General Description.

Cleveland is located in the northwestern corner of Liberty County, and is surrounded by forests and thickets on every side. The oil field development which began about 40 years ago has helped this city to grow. Many oil pipelines criss-cross along the northern and eastern sides of the city.

The ground elevations range from 165 feet at the northern side of Cleveland to 140 feet at the southwestern edge of the city, where the East Fork of the San Jacinto River flows. The river is only about a quarter of a mile from the nearest residential area at its closest point. Drainage is fairly good in this part of the county and the flow direction is generally toward the

south.

Federal Highway 59 and the Southern Pacific Railway are parallel and bisect the city generally in a north-south direction. State Highways 105 and 321 extend from downtown Cleveland in both eastern and western directions. The Atchison, Topeka and Santa Fe Railway passes through the city in an east-west direction.

B. Sanitary Landfill Site Selection Constraints.

The city of Cleveland is surrounded by forests in every direction. The feasible lands for sanitary landfill use are the uncultivated open areas within these dense forests. In the future it appears that the city will be extended principally in both northern and southern directions. The eastern side is almost covered by forests and relatively few areas appear to be available for possible sites, thus the location of the potential sites would seem most likely to be on the western side of the city. But the county boundary lines limit somewhat the selection of sites both in the northern and western directions.

C. Potential Landfill Sites.

Four sites were selected to serve Cleveland. From the data shown in the table of estimated population, the corresponding hauling radius of solid waste for a city the size of Cleveland is 6 miles.

The description of each site is as follows:

a. Site 1: This site is a pasture land and is located to the west of FM 1010 by a distance of about 1300 feet.

The area is surrounded by thickets and forests on three sides, excepting the northern side. There are no residential buildings and wells within 500 feet. The nearest house

is toward the northeast and is separated from the area by about 1050 feet. The Site elevation is about 105 feet. The Site consists of 37.8 acres which is enough to satisfy the area requirement for the 1990 estimate of needed space. The ground water table is relatively low. The soil type is identified as a fine sandy loam of the Hockley-Segno Association which has a moderately drained character. There is no stream or bayou in the vicinity.

The hauling distance of refuse from downtown would be about 4 miles. There is no existing road leading to this site. A new access road should be provided near the northeast corner to join FM 1010 which passes about 400 yards away. The route for hauling the refuse could be as follows: downtown to Plum Grove Road, thence to FM 1010, and then onto the newly built access road to the site.

b. Site 2: This site is at present uncultivated cleared land like Site 1 located inside the forested region with an opening only on its northern side. A farmhouse is located about 400 feet from the northeast corner of the site. An existing road passes through the forest on the western side of the site and this leads to a county road on the southern side. The area is about 34.4 acres, which is less than the 1990 estimate of needed area by 1.2 acres, but it is assumed that the space would be close enough to satisfy the requirement.

The eastern portion, comprising about 40% of the area, is a marsh land and an irrigation well is located at the southern side of the site. The surface of this site is not much above the ground water table.

The distance from downtown Cleveland to the site is about 5 miles. The refuse could be carried from the originating area via Highway 59 south to the place called Williams, thence west on the county road and then north on the smaller road through the forest to reach the site. It appears that access would be better by using the existing road, and improving it to meet the requirements, rather than by creating a new access road.

Soil in this site is Splendora fine sandy loam. It is a good cover material for landfill operation. There are no streams around the site.

c. Site 3: This site is located near the southwestern outskirts of the urban area. It is totally surrounded by dense forests. The East Fork of the San Jacinto River runs along its eastern side with a short separation distance of about 200 feet. Ground elevation is 125 feet above sea level. Since it is near the riverbank, flooding at some time is inevitable. Proper protection using dikes or other operational methods will be necessary to minimize this potential flooding problem. The soil type at this site is Kaufman clay. It is prone to swell and is thus deemed to be poor material for landfill covering. The water content of the ground is fairly high. Water contamination of the fill could be severe. The land area is 44 acres, much more than the 1990 requirement. It is identified as undeveloped land.

The distance for hauling refuse to the site is about one mile. An existing forest road leading to the site would have to be improved and widened for general use. The hauling

route could start from downtown, pass along Southline Street to Highway 105, then west to beyond the junction with FM 1725, and then after a short distance turn south into the existing access to the site.

d. Site 4: This site is located between the East Fork of the San Jacinto River and FM 1725 on the western side of Cleveland. The ground elevation is 130 feet above sea level. Its western part is shielded by a forest. There is a lake on its northern side and a small creek bank to form a general screen of the site.

The site is a pasture land with an area of 45.8 acres. The soil type is Susquehanna fine sandy loam and the moisture content of the soil is fairly high.

The hauling distance of refuse is about one-and-one-half miles from downtown Cleveland. A new access road about 500 feet in length would be required on the southwest corner to connect to FM 1725. The hauling route would be as follows: downtown to Southline Street, thence to Highway 105, and on to FM 1725, and then to the site.

D. Matrix Rating Table.

The rating table for each site is shown in Table III. The estimated areas required for refuse disposal from 1970 to 1980 and from 1980 to 1990 are given in the table also.

E. Final Recommendations.

Site 1 has the most favorable rating of the four as a potential site for a sanitary landfill for Cleveland. From an economical standpoint, this site should be quite suitable for conversion into a sanitary landfill. The purchasing cost per acre should be

Table III. Matrix Rating System for Site Selection.

Cleveland, Liberty County

Rating Item	Proposed Site			
	1	2	3	4
Land-Use	0	0	0	0
Drainage	2	8	5	8
Soil Type	0	0	10	0
Road Surface	3	7	3	2
Accessibility	3	3	3	3
Total Rate	8	18	21	13
Area (acre)	37.8	34.4	44	45.8
Estimated Area	1970 - 1980: 12.2 $\Sigma = 35.6$ 1980 - 1990: 23.4			
Needed (acre)				

less than that of the other sites, since it is not located by the public roadside and the land does not appear to be used significantly now. The expense of removing the trees inside the site could be offset by the economical purchasing of this pasture land.

To be useful as a landfill an access road would be required. However, this may be another advantage of this site because the road can be constructed so as to enhance the landfilling operation. The area is rectangular in shape and is protected by natural forests. The wind blowing of litter can be minimized at this site. The possibility of objections about landfill operation from residents would be negligible because of the surrounding forests and the

absence of residents in the vicinity.

Since the site is remotely located on the southern side of Cleveland and there are no prominent surface waterways, the possibility of contamination of public water quality is not likely. Airborne environmental problems will be minimized also.

References

1. "Texas Almanac - 1972-1973," The Dallas Morning News.
2. "The Handbook of Texas," The State Historical Association, 1952.
3. "Population Projections, 1970-2020 for the Gulf Coast Planning Region," Houston-Galveston Area Council, April 1, 1972.



DAYTON-LIBERTY, LIBERTY CO.

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CASE STUDY OF MONTGOMERY COUNTY

Montgomery County lies in the southeastern part of Texas in the Western Gulf Coastal Plain. It is bordered by Walker County on the north, San Jacinto and Liberty Counties on the east, Harris County on the south, and Waller and Grimes Counties on the west. Peach Creek is the boundary with San Jacinto County, and Spring Creek forms most of the boundary with Harris County. Montgomery County, which is adjacent to the Houston metropolitan area, has an area of 1,090 square miles. The county seat, Conroe, is located in the rolling forested plain area, 37 miles north of Houston, 97 miles northwest of Beaumont, 140 miles east of Austin and 204 miles south of Dallas.

The topography of Montgomery County is hilly and rolling. Forests cover about 81% of the land; however this percentage has decreased 3% in the past two years. The county is bountifully supplied with a variety of both softwood and hardwood timber, especially various classes of pine, namely short leaf and loblolly pine. Oak, gum, elm, ash, holly, hickory, magnolia, black walnut and a number of other hardwoods are found.

A. POPULATION

Montgomery County has an urbanized economy now as it is in the Houston Metropolitan area. There are many residential developments; the number of subdivisions in the county, estimated from varying sources, range from 250 to 500. There is at present only one major urban area and this is the city of Conroe.

In this predominantly rural county, the city of Conroe represents 80 percent of the urban population, which is equivalent to only 24 percent of the total county population. Projections for county population distribution in 1990 indicate 55 percent of the urban population and 29 percent of the county population will be located in or near Conroe. The noticeable reduction in the urban percentage represented by Conroe is attributable to the extensive subdivision development on the shores of Lake Conroe and in the vicinities adjacent to the city of Conroe.

The county is experiencing a rapid suburban development and within twenty years much of the present rural portion of the county will be urbanized. Montgomery County is undergoing one of the most rapid urbanization processes of any area in the United States.* It is estimated that over 1200 families per year are moving into Montgomery County and that this trend will increase. See Table I.

TABLE I
POPULATION GROWTH IN CONROE AND MONTGOMERY COUNTY

<u>Year</u>	<u>Conroe</u>	<u>Montgomery County</u>
1930	2,457	14,538
1940	4,624	23,055
1950	7,313	24,504
1960	9,192	26,839
1964	12,945	34,980
1967	13,960	40,362
1969	15,500	43,560
1970	16,932*	49,479*
1980	19,000**	134,000**
1990	33,000**	300,000**

* Based on Texas Almanac

** Based on "Population Projection", April 1, 1972, Gulf Coast Planning Region, Houston-Galveston Area Council

The population shifts combined have had a tremendous impact on changing the role of agriculture in Montgomery County. The simple fact of acreage being taken up by an urban society has caused a decrease in land available for agricultural production.

This trend will increase due to the geographic location of the county. Many of these land units are owned by people working in nearby metropolitan centers and making their homes in Montgomery County.

B. GEOLOGY

Montgomery County can be described as a gently rolling plain in the northern and western portions; but the southern and eastern part is almost level. The maximum elevation is 440 feet, and the southern portion of the county is only 45 feet above sea level. Vegetation in this area is characterized by a heavy, dense growth of trees.

The slowly rising coastal plain on which Montgomery County is located stretches 300 miles inland from the Gulf. The sedimentaries are of the Miocene-Oligocene period with the older rocks being beneath the younger ones. In some parts deposits of the Pleistocene period overlay the marine sediments. The rock structure has a gentle slope toward the Gulf in a southeasterly direction. Other geological formations consist of the salt domes of the Gulf Coastal Plains. Hills and ridges of the county are the result of deposits and uplifts of the coastal plain and the erosion of these by streams and weather. The main formation of this type is the Lissie sandstone formation near the town of Willis, north of Conroe.

C. PHYSIOGRAPHY AND DRAINAGE

The topographic surface varies from almost flat near the large streams and in the southern part of the county to hilly in the northern part. The county is in the San Jacinto River basin in which the primary drainage tends to flow from northwest to southeast. The large streams are the West Fork of the San Jacinto River, Peach, Spring, Stewart, and Caney Creeks. Secondary drainage patterns lie approximately west to east principally along Lake and Spring Creeks. The primary drainage is controlled by the southeasterly slope of the land surface while the secondary drainage is controlled to a large extent by the occurrence of alternating outcrops of sand and clay.

The West Fork of the San Jacinto River has a stream gradient of about 5 feet per mile in the northern part of the county and about 3 feet per mile in the central and southern parts. Caney Creek has a gradient of 8 to 12 feet per mile in the northern part of the county and about 5 feet per mile in the central and southern parts. Spring Creek has a gradient of 5 feet per mile in the southwestern part of the county and about 3 feet per mile in the southeastern part. All of the principal feeder streams in this county are subject to flooding after heavy rains, severe at least once yearly.

There are a number of natural and man-made lakes in Montgomery County. In addition to the surface water, the county has a surface structure which dips toward the southeast and forms catchment basins for underground water. Wells with moderate to large flows obtain water from sands of the Catahoula, Oakville, Lagarto, Goliad, Willis, and Lissie formations.*

*More detailed discussions of the geology of the area can be found in the publications of the Bureau of Economic Geology, The University of Texas at Austin.

D. SOILS

Montgomery County contains 697,600 acres of land and consists of eight different soil associations. These are listed below*:

1. Conroe association: Deep, gently sloping to rolling, moderately well drained and well drained, sandy soils that have clayey lower layers
2. Splendora-Boy-Segno association: Deep, nearly level to gently sloping, somewhat poorly drained to well drained, loamy and sandy soils that have loamy lower layers
3. Wicksburg-Susquehanna association: Deep, gently sloping, well drained and somewhat poorly drained, sandy and loamy soils that have clayey lower layers
4. Sorter association: Deep, level, poorly drained soils that are loamy throughout
5. Ferris-Houston Black-Kipling association: Deep, gently sloping to rolling, firm, mainly clayey soils that have a high shrink-swell potential
6. Albany-Tuckerman association: Deep, level to gently sloping, somewhat poorly drained and poorly drained, sandy and loamy soils on low stream terraces
7. Tuscumbia association: Poorly drained, very firm, clayey soils on flood plains
8. Hockley-Katy association: Deep, level to very gently sloping, well drained to somewhat poorly drained, loamy soils that have loamy or clayey lower layers

E. CLIMATE

The climate of Montgomery County is dominated by the weather conditions of the Gulf of Mexico. The county lies within a humid, sub-tropical belt that extends northward in the spring, summer, and fall months, from the Gulf Coast region. In winter, the inter-action of cooler continental air from the north with the moist tropical air

* From the Soil Conservation Service general soils map of Montgomery County.

from the Gulf is frequent over this region resulting in abundant rainfall. Rainfall is more or less evenly distributed throughout the year. Annual precipitation averages about 47 inches. The heaviest short periods of rainfall are associated with drying tropical disturbances that sometimes enter the Texas Coast and move northward through East Texas in the early fall. Winters are mild while summers are hot and humid. The average daily maximum temperature is 63 degrees in winter and 94 degrees in summer.

F. GENERAL CONSIDERATIONS AND CONSTRAINTS ON SITES

In order to develop a satisfactory system for the disposal of solid waste without causing environmental pollution, local conditions must be taken into consideration. Consideration must be given to the patterns of land development and population growth as well as to future land use plans when selecting potential landfill site locations. Since sanitary landfills during the period of operation are not aesthetically pleasing, a reasonable amount of isolation is essential to minimize nuisance and public opposition. A site should be located in a relatively undeveloped area with a minimum number of residents having a view of the operation or being affected by refuse hauling vehicle traffic. Exposure of the landfill to view from major highways is often considered to be objectionable.

To minimize hauling costs and the nuisance from refuse hauling vehicles, landfills should be located as close to refuse generation centers as possible and be accessible via the major transportation arteries. The location of the site directly affects the overall

refuse collection and disposal cost.

Sites must be provided with all weather access and have routes selected to avoid travel through residential areas. Access roads should safely accommodate even the largest hauling vehicles and should not have excessive curves, steep grades, narrow bridges and low underpasses.

Large landfill sites have inherent advantages over smaller sites. A large site may provide greater isolation for the landfill operation and provide a greater assurance of continued long-term disposal operation. The unit disposal costs for large sites may be expected to be lower due to a lower land cost per acre and a higher tonnage of refuse handled per year. The difficulty in acquiring a large site may be no more than that in acquiring a smaller one and the long-term public opposition will be less because large sites reduce the frequency of site relocation.

The required cover thickness for use over the refuse should be determined by soil analysis. Sandy loam is generally the best material for cover because it compacts easily and well. A minimum of six inches should be used for the daily cover, and not less than two feet for the final top layer or sealing. Very sandy soil may have to be spread in thicker layers to prevent penetration by insects and vermin. Soil with too much clay will crack and allow vermin to enter the fill.

Proposed lift depths will vary with the type of refuse, the soil conditions, climate and terrain. The normally recommended maximum depth for a lift is 6 to 8 feet. In practice this can be anything from 2 to 15 feet, sometimes even more.

The most advantageous site is one which provides suitable cover materials. Cover material should be relatively free of organic matter, tree roots, branches, and stones over six inches in diameter. It should exhibit stability during all weather conditions, and be easily excavated, transported, and spread.

The ground water level should not be allowed to reach the refuse nor should precipitation or surface water be permitted to infiltrate the fill. Refuse should be placed no deeper than 3 to 5 feet above the seasonal high ground water table or the bedrock layer. Swamp areas and land subjected to periodic flooding should be eliminated from consideration as potential landfill sites unless special operational precautions are used to safeguard water quality.

Surface drainage from tributary areas must be diverted from the site. Direct precipitation on the site should be allowed to flow off on the surface so as to prevent percolation into the refuse and subsequent formation of leachate. The rate of percolation depends upon the permeability of soils, the slope of the land, and the size of the drainage area. By proper grading and construction of artificial barriers it is possible to prevent problems arising from surface water.

G. USE OF AERIAL PHOTOGRAPHY

The use of aerial photography is ideal for preliminary selection of potential sanitary landfill sites. The up-to-date synoptic information and inferences obtained from aerial photography supplement information obtained from maps, reports, and from field and laboratory investigations. When properly correlated, the information from all these sources provides the background for planning within the study

area.

The aerial photography used in this study was taken on NASA aircraft mission No. 145. Color positive transparencies and color IR positive transparencies were used. The detailed information concerning the photography of mission No. 145 is given in Chapter II.

H. CONROE

Conroe, the county seat of Montgomery County, is located 37 miles north of Houston. Geographically it is in the central part of the county. The roads Interstate 45, U. S. 75, and FAP 105* all cross within the city.

Conroe was incorporated in 1885. The economy of the city and the county depended upon timber, lumber, and a limited amount of agriculture until oil was discovered in 1932. This changed the economy of the county. The Conroe oil field is one of the major producing fields of Texas with 10 million to 12 million barrels per year being produced. Recently established industries have added to the economic stability and urban growth of the area. The Conroe oil field is located toward the southeast of Conroe and within a 10 mile radius of the heart of the city.

Construction of Lake Conroe to the northwest of the city was completed in late 1972. This 18,000 acre lake will offer many recreational opportunities for the area. There are also numerous smaller lakes in Montgomery County.

According to the Texas Water Plan the capacities of Lake Conroe in thousands of acre feet are: flood control 0.0; conservation 420.5;

*Federal Aid Primary Road

dead 9.8; and total 430.3.

According to the criteria of haul distance which was adopted for this investigation the reasonable haul radius for Conroe is 8 miles. Table II contains the listing of haul distances vs. population as developed for this investigation.

TABLE II
HAUL DISTANCE

Population	Radius from centroid of waste generation
0 - 10,000	4 miles
10,000 - 25,000	6 miles
25,000 - 50,000	8 miles
50,000 - 100,000	10 miles
100,000 - 500,000	15 miles
> 500,000	20 miles

Table III gives the projection of population, solid waste, and landfill land requirements for the city of Conroe.

TABLE III
LAND REQUIREMENTS FOR WASTE DISPOSAL

Population		Total Waste (W) P ave. x 10 ac.ft/yr. /10,000 pop. P ave. x 13 ac.ft/yr. /10,000 pop.		Total Acreage = Acres/10 yr./10,000 pop. $W \times \frac{1}{6 \text{ ft. ave. depth}} \times 10 \text{ yr.}$	
1970	11,969	1970-80	1980-1990	1970-80	1980-90
1980	19,000	15.49	33.8	25.8	56.5
1990	33,000				

I. POTENTIAL SANITARY LANDFILL SITES

Six sites within the 8 mile haul radius were selected for study. These are shown as white polygons with Roman numbers on the attached

aerial photograph of the Conroe vicinity, and are described as follows:

- (a) Site 1 - North of FAP 105 and the West Fork of the San Jacinto River, west of Live Branch Road; site which is only a short distance from the dam of Lake Conroe.
- (b) Site 2 - East of FM* 1314 and Little Caney Creek, south of FAP 105, northwest of Four Corners, north of Grogan Road; site which is a half mile distance east of Conroe Memorial Park Cemetery.
- (c) Site 3 - South of Old Montgomery Road, Gulf Colorado and Santa Fe Railroad, west of Interstate 45, north of Camp Madeley (Girl Scouts of America), east of the West Fork of the San Jacinto River; site which is a short distance south of Golden Gate Cemetery.
- (d) Site 4 - East of Missouri-Pacific Railroad, south of the East Fork of Crystal Creek, north of Sunset Ridge; site which is a half mile distance east of Camp Agnes Arnold, Girl Scouts of America.
- (e) Site 5 - East of Missouri-Pacific Railroad, south of the East Fork of Crystal Creek, west of FM 1484; site which is one mile distance from Montgomery County Airfield and about that far from FM 1484.
- (f) Site 6 - East of FM 1484, north of FAP 105, south of Montgomery County Airfield; site which is a half mile distance south of Montgomery County Airfield.

According to the soil survey conducted by USSCS, the soil types of the potential sites are as follows, see Table IV.

*Farm to Market road

TABLE IV
SOIL TYPES FOUND AT SELECTED SITES

Site No.	Soil Type and its Percentage
1	SuC 30%; Hs 15%; SuD 5%; Bu 10%; FcC2 20%; WkC 7%; others 13%
2	Sp 95%; Se 5%
3	Tk 90%; CoC 10%
4	Bu 5%; An 40%; Sp 30%; So 15%; Fs 10%
5	SuC 60%; Se 15%; Sp 15%; CoC 20%
6	Se 15%; Su C 70%; Sp 15%

Soil Legend*	
<p>The first capital letter is the initial one of the soil name. A second capital letter, A, B, C, or D, shows the slope. Most symbols without a slope letter are those of nearly level soils, but some are for soils that have a considerable range of slope. The number 2, in a symbol, indicates that the soil is eroded.</p>	
Symbol	Name
An	Angle fine sandy loam
Bu	Burleson clay
CoC	Conroe loamy fine sand, 0 to 5 percent slopes
FcC2	Ferris clay, 1 to 5 percent slopes, eroded
Hs	Houston Black clay
Se	Segno fine sandy loam
So	Sorter silt loam
Sp	Splendora fine sandy loam
SuC	Susquehanna fine sandy loam, 1 to 5 percent slopes
SuD	Susquehanna fine sandy loam, 5 to 12 percent slopes
Tk	Tuckerman loam, heavy substratum
WkC	Wicksburg loamy fine sand, 1 to 5 percent slopes

* For complete reference see USECS Soil Legend of Montgomery County.

J. MATRIX RATING TABLE

Table V shows the numerical values of the six sites evaluated regarding their use as sanitary landfills.

TABLE V.
MATRIX RATING SYSTEM FOR LANDFILL SITES
MONTGOMERY COUNTY

Criteria	1	2	Site No. 3	4	5	6
Land Use	5	5	5	5	5	2
Drainage	8	5	5	5	5	8
Road	10	10	10	10	10	10
Soil Type	5	0	5	4	3	0
Accessibility	3	3	3	3	0	0
Total	31	23	28	24	23	20
Area (acres)	120	100	50	75	100	90

K. FINAL RECOMMENDATIONS

The proposed landfill sites selected for Montgomery County provide sufficient space for refuse disposal to satisfy the present demands and the future needs of this county for the next two decades.

Site No. 6 appears to be the most favorable, although Site No. 4 and 5 are for practical purposes just as good. The vicinity abounds in fine sandy loam, ideal for landfill cover material. The ground water table is no problem and proper access could be constructed easily. Site No. 6 has a slight advantage over No. 4 and No. 5 because of its low land use. It presumably would be more economical

to purchase than land having a more developed land use.

The natural resources of the county appear to be extremely well adapted for outdoor recreational use. Because a sanitary landfill can accommodate large and widely varying amounts of waste at low operating costs, it is the most efficient disposal method for recreational areas. To be workable a regional solid waste program for the county would probably require coordination of administrators of the city and county, and various state and federal agencies.

The objectives of a regional solid waste management program are to remove and dispose of all solid wastes in a manner that maintains high standards of sanitation at the lowest cost. In rural communities having small scattered populations producing correspondingly low quantities of solid waste, providing an adequate refuse collection and hauling service is often impractical. Where these communities are remote from the central disposal facilities, there is merit to considering the use of "mini-transfer" stations. Under the proposed solid waste management program, containerization stations could be installed and managed by the county. These containers could be taken to the sanitary landfill site as often as the seasonal activities of the recreational public required.

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CHAPTER V

SPOIL SITES

Introduction

One of the objectives of the investigation was stated thusly: "Identify locations suitable for disposal of the spoil from dredging activities as this is another form of solid waste, and one which can readily contribute to estuarine degradation during storm runoff."

Since the time of that statement, much information has been gathered in an effort to determine the usefulness of remotely sensed data to the selection of potential spoil sites. A brief history of the Houston Ship Channel and description of the dredging activities are necessary for an understanding of the environmental impact of spoil materials.

The City of Houston constructed an oceanic port by dredging approximately 50 miles from the ocean in the early 1900's (1). The first major ocean going vessel docked at a wharf near the Turning Basin in 1915. The Houston Ship Channel, as the dredged passageway is called, represents an estuarine system which has undergone substantial environmental modification and which is subjected to excessive levels of environmental pollution. The channel and surrounding area are shown in Figure 1. A great deal of the pollutorial input is in the form of a large sediment load contributed by agricultural and urban runoff, municipal sewage effluents and the wastes of a vast industrial complex. The physical

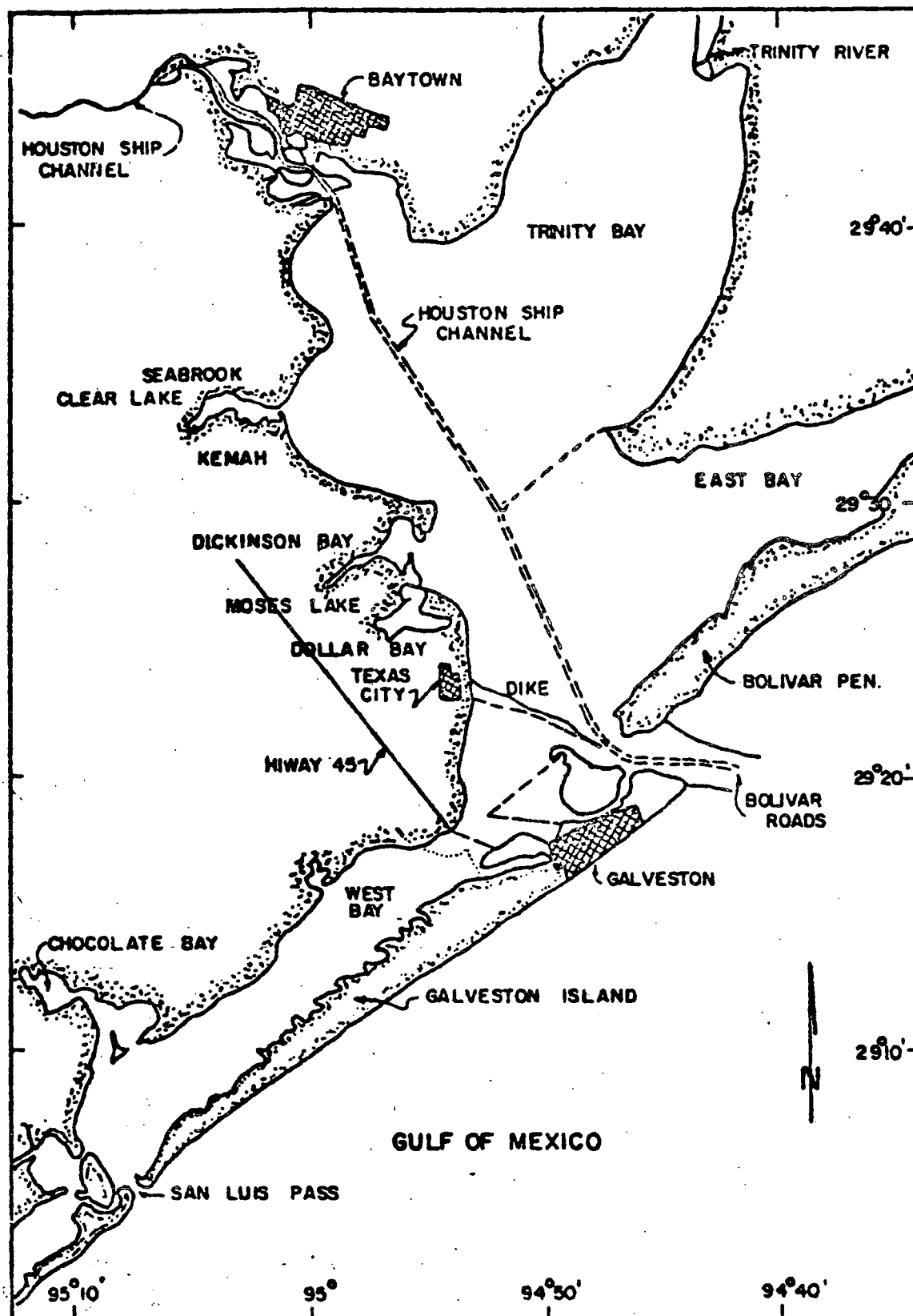


FIGURE I

HOUSTON SHIP CHANNEL AREA

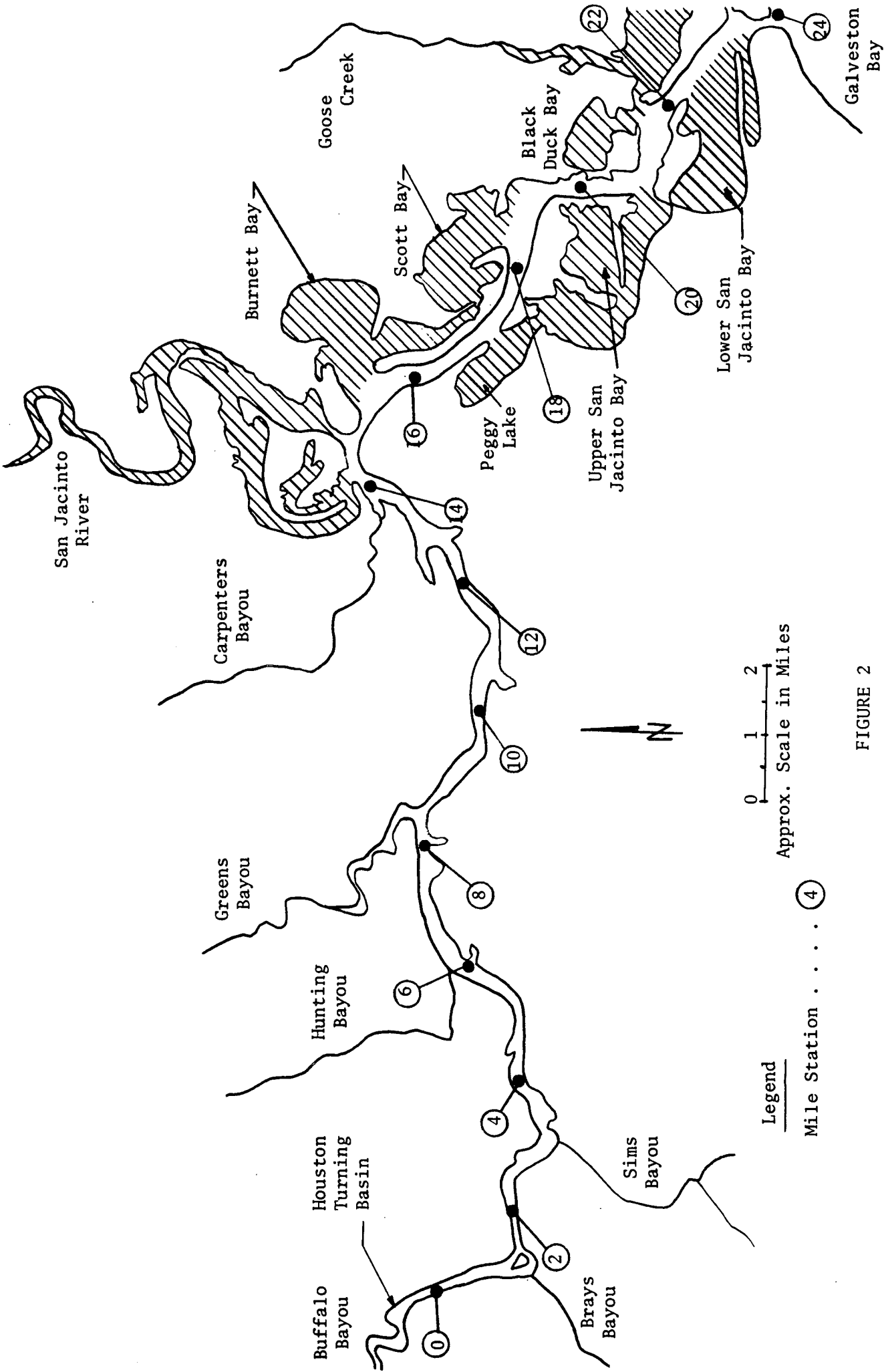
volume of the sediments and the rate of sedimentation is important to those responsible for maintaining navigation and to the dredging industry which is responsible for the removal and redeposition of the material. Two agencies, the Port of Houston Authority and the Corps of Engineers-Galveston, cooperate in the maintenance of the channel.

The channel has considerable economic impact upon the Houston area. A 1967 study estimated that \$400 million of income was generated by the port (2). At the time of the study one out of every seven Houston residents owed his employment to the new port, and the tax contribution amounted to \$140 million a year.

Channel Description

The channel must be maintained at a depth of approximately 40 feet so that ocean going vessels may dock near Houston (3). From the Gulf of Mexico to a point just above Sims Bayou this 40 foot depth is maintained by dredging while a 36-40 foot depth is maintained from that point up to a short distance above the Turning Basin. Some dredging is done above the Turning Basin up to and just above Turkey Bend. Dredging operations continue throughout the year to keep the depth required in the channel for navigational purposes. Figure 2 illustrates the upper portion of the channel in more detail than that shown in Figure 1 (4).

From the inlet of the channel at Bolivar Roads up to Morgan's Point at the end of Trinity Bay, the dredge materials are deposited at sea. The major sediment loads in this stretch of the channel are due to the movement of the bay's bottom sediments into the channel due to wind caused currents which shift and carry the



Legend
 Mile Station (4)
 Approx. Scale in Miles
 0 1 2

FIGURE 2
THE HOUSTON SHIP CHANNEL FROM TURNING BASIN TO MORGAN'S POINT

sediment deposits. These sediments are then deposited by gravitation into the deeper channel bed.

The sediment load from Morgan's Point to a location near where Lockwood Drive crosses Buffalo Bayou (see Figure 3) is mainly due to the settling of the agricultural and urban runoff, municipal effluents and industrial waste. This sediment load settles at varying rates along this portion of the channel. Sedimentation rates in 1969 generally averaged 2.5 ft./yr. in the upper twelve miles (from Lockwood Drive just above the Turning Basin, to a distance down the channel of twelve miles), 2.0 ft./yr. from mile 12 to mile 17 and approximately 4.0 ft./yr. in the lower five miles of this section from approximately Scott Bay to Tabbs Bay (4). This increase in the five mile stretch from approximately Scott Bay to Tabbs Bay is due to the heavy loading in the influent from the San Jacinto River. Figure 3 illustrates the volume of the average sedimentation rate in cubic feet per year per foot for dredging cycles Number 1 and 2 for 1969. The relatively large volume of sediment material is due to the fairly flat topography of the area, the blocking action of the bay areas, and the immense waste loadings placed in the channel. Dredge materials from this portion of the channel are redeposited in spoil site areas located near the channel. These spoil site locations are illustrated in Figure 4.

Dredging has been done since the early 1900's. Materials were placed in low areas near Buffalo Bayou with additional land acquired as space was needed. Initially these areas were small in size; however, sites now contain anywhere from 100 to several

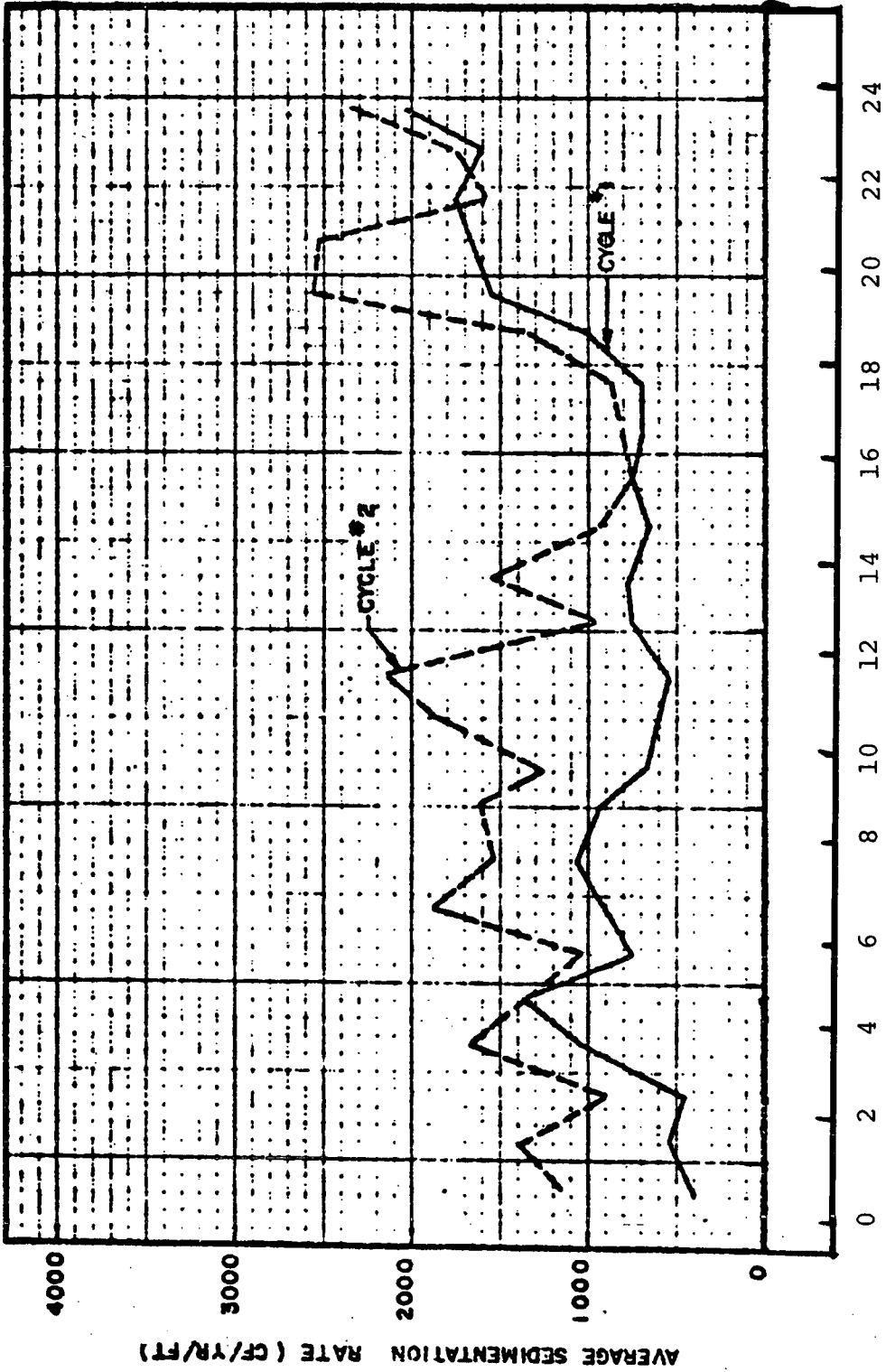


FIGURE 3
CHANNEL MILES FROM TURNING BASIN TO MORGAN'S POINT

hundred acres. Most sites now in use were acquired 20 to 30 years ago. The capacity of each site is not only a function of the acreage of the site but also of the levee height. Actually the sites serve as sedimentation basins. It was estimated, in a study pertaining to dredging on the New Jersey coast, that approximately 6 cubic yards of mud laden water had to be removed from a channel to deposit one cubic yard of sediment in the spoil sites (5). Only gravitational settling occurs in the basins as no chemical coagulation is attempted. Therefore, the return flow leaving the spoil site carries a heavy load of suspended solids back to the channel. This load of suspended solids consists of the smaller colloidal particles that do not settle until the quiescent waters of the bay areas are reached. However, the turbidity caused by this return flow from spoil sites is only a minor portion of the total solids loading occurring along the channel and is not a major problem. Compared to the municipal sewage effluents and industrial wastes this flow in terms of pollution potential is minute.

As previously stated, the actual capacity of each site depends on the levee height. It is possible, related to a cost function involving purchasing new areas and construction of new fluid transmission lines, that when a site capacity is nearly exhausted, the surrounding levee system height may be increased to accommodate more material.

In conferring with the Port of Houston Authority (3) and the Corps of Engineers-Galveston (6), it was learned that the main criteria for selecting potential spoil material site locations were that the location be near the channel and that the area be undeveloped

or sparsely populated. Both criteria are related to economic considerations. The site locations need to be as near as possible to the channel to minimize pipe transmission costs, including pumping cost. Another consideration in selection of sites deals with the ability of the Port of Houston Authority to obtain the right-of-way for transmission lines. This is important since the majority of spoil material is transported to the spoil sites by pipe lines. The only time trucks are used to transmit the spoil material is when new dredging, in the form of channel improvements, such as wharf construction, is occurring.

Spoil material consists of fine sands, silts and clays. Organic matter from both municipal sewage effluents and industrial discharges plus heavy metals from other industrial effluents are also contained in the spoil material. One noted marine geologist (2) estimated that approximately 35 percent of dredged materials are polluted and the remainder are totally acceptable for disposal at sea or on land. Due to the industrial waste concentrations and the stagnant features of flow in the Houston Ship Channel, the polluted percentage is thought by some to be higher than the estimate made by the marine geologist. Decaying organic matter and heavy metals, most of which are toxic to biological life at various concentrations, produce some odor at spoil sites. The Authority noted that some complaints due to odors had been received but none of major importance. One instance of pollutional aspects occurred in Galena Park where hydrogen sulfide gas produced in the spoil site was responsible for paint peeling off houses near the site (7). No complaints have been received pertaining to the possible

pollutional aspect of the return flow from the spoil areas.

The Corps of Engineers has done some preliminary studies on the capacity of present sites and the future availability of disposal site locations. Table I lists the different spoil sites in use in 1967. Comparison with Figure 4 indicates how the site locations have changed since 1967.

New sites will be needed in the future but this need is not critical at present. The capacity of present sites may be increased by constructing higher levees. However, the Corps is aware of the possible need for channel enlargement to allow larger tankers to dock near Houston. This possibility exists due to the limited and rapidly diminishing supply of raw material (petroleum) stocks from domestic sources (2). Energy experts estimate that by 1975 the United States will not be able to meet its mounting fuel requirements without increased imports. Increased imports mean not only more ships but also larger ships.

Application of Remotely Sensed Data to Spoil Site Selection

As already mentioned, site selection is governed primarily by the distance from the channel and the extent of area development. By the use of aerial photographs the land areas adjoining the channel may be investigated. This technique allows the investigator to quickly study the entire channel area with current land use data regarding this rapidly developing region. From the photography general trends in the area development may be noted and immediately many areas may be excluded from consideration due to the high population or industrial density.

TABLE I: HOUSTON SHIP CHANNEL SPOIL DISPOSAL AREAS - 1967

Spoil Area	Existing Capacity (cu.yds.)	Life of Existing Area (yrs.)	Shoaling Rate (cu.yds./yr.)	Easement Expires	Can Be Restored	Acres
Spillman Island	8,500,000	10	825,000	1980	Yes	950
Alexander Island	3,400,000	7	500,000	----	Yes	660
Peggy Lake	1,400,000	10	150,000	1968	Yes	220
Lost Lake	4,300,000	8	525,000	1971	Yes	610
San Jacinto Ord. Depot	475,000	1	435,000	1968	No	---
West Jones	660,000	1	550,000	1982	No	---
Rosa Allen	270,000	2	112,000	1982	No	128
Clinton	7,400,000	15	500,000	1981	No	580
Stimson	300,000	--	-----	Expired	Yes	92
Glendale- Brownsville	530,000	--	-----	Expired	Yes	190
Filter Bed	250,000	--	-----	Expired	No	90

The best analysis procedure is to study the photography in zones arbitrarily selected equidistant from the channel on both sides of the channel. Zones of approximately 2 and 6 miles distance from the channel were used. These zones are shown in the overlay directly above the photograph of the channel. Areas of industrial and residential development are indicated with the use of crosshatching on the overlay.

This technique proves to be a quick and efficient method to direct site location investigation to the areas which can potentially serve as spoil site locations. After the indicated analysis had been accomplished it was concluded that more information is necessary than that obtained in the small scale aerial photography to actually select spoil site locations. The primary reason for this conclusion was the fact that the selection criteria to be considered in preliminary site selection are close proximity to the channel (to minimize pipe line lengths) and a large area - greater than 100 acres - in a relatively undeveloped state of land use.

After consideration of both distance and land use development, which generally indicate large areas, it is necessary to refine the analysis and actually obtain a specific area for use, either by lease or purchase. When a specific location has been acquired the photography is again useful as an information source as is pointed out in an example site selection which follows.

Review of the overlay indicates that open areas are generally located to the north of the channel. Probably extension of present transmission pipe lines would be the most economical method of

development of new spoil sites. In this manner present rights of way for the pipe lines must only be extended beyond the present spoil site and not the entire distance from a potential site to the channel.

One example of site location has been prepared to indicate that the photography can and does illustrate the potential land surface physical features which may inhibit the placement of spoil transmission pipe lines. The overlay illustrates this benefit of photographic interpretation. A relatively large area has been indicated on the overlay as a potential spoil site by the illshaped rectangle containing the letter A. Ground surveys may be directed to this general area to determine the best possible site. The area chosen meets the requirements of spoil site selection -- close proximity to the channel and sparse development.

After a potential site has been selected, use of the photography illustrates the current topography and land use development, which in turn determine the most likely route to be used for the pipe lines. These lines are from 18" to 30" in diameter and are placed on the ground surface except to cross railroads, highways and plant or residential developments.

Conclusions

The Houston Ship Channel is surrounded by some of the most rapidly developing area in the United States. Both the industrial and people populations of this area are increasing at tremendous rates. As the area around the channel becomes saturated with industrial and residential development, it becomes a more severe problem to locate spoil disposal sites.

The use of remotely sensed data is a definite aid to efficient selection of sites. Two major aspects of the use of the photography are as follows:

- 1) Recent photography of the channel area gives up-to-date data of the developments that are occurring. By excluding those areas which have become saturated population-wise, ground surveys may be directed toward those areas which have disposal site potential.
- 2) Furthermore, after a potential site has been chosen, photography can be used to determine the best feasible pipe line routes to the potential site.

Again it should be noted that the major benefit of small scale photography is the fact that it is an up-to-date information source and offers a synoptic view. The importance of this in application to a rapidly developing area cannot be overemphasized.

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HOUSTON SHIP CHANNEL

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CHAPTER VI

RECOMMENDATIONS FOR FURTHER WORK USING THE SAME PHOTOGRAPHY

Three major objectives are planned for the second year of the contract. These objectives can be met using the color (1:120,000) and color IR (1:60,000) photography now on hand in the UH project office. The objectives are:

(1) To develop from the photography an overall regional drainage model of rainfall-infiltration-runoff. This model will be compared with whatever partial hydrological models have been developed for this region by other methods.

According to the hydrological cycle, once precipitation reaches the ground, it will (1) infiltrate the soil and become ground water, (2) collect on and flow in surface depressions and thus become surface water, (3) evaporate, and (4) be transpired from vegetation. Since evaporation and transpiration quantities are usually determined as regional approximations, it is important to find a way to calculate accurately the runoff volume so that the infiltrated quantity can be estimated more accurately.

(2) To chart the erosion characteristics of the soils within the region and the sedimentation patterns of the major streams. A study of stream activity and associated landforms is essential to any drainage study. Of importance in this analysis are stream gradients, drainage density, basin shape and size, side slopes and basin length-wise slope. The quantity of runoff will be related to factors such as vegetative cover, time of concentration, area of basin, and intensity of rainfall.

Sources of sediment can be inferred from aerial photography.

There is general surface scouring of the land and the beds of streams. The least sediment is derived from land whose surface texture is open and whose soil is permeable, permitting infiltration of water. Discoloration of water on color IR photography can be inferred to be caused by turbid or sediment filled water. The presence of erosion rills and scars, and a minimal vegetative ground cover indicate sources of sediment.

(3) To demonstrate a rational method of utilizing the synoptic character of small scale photography to determine greenbelt requirements for a region and show how their logical patterns and locations can be planned.

There are three functions for open space: (1) recreational opportunity, (2) environmental amenity, and (3) maintenance of natural plant and animal processes. These three functions share a common factor -- water. Recreationists, sociologists, and scientists all agree that water is the focal point about which open space should be developed.

Water courses, and the ridgelines between, serve to establish visual amenity and help prevent encroachment of noise, insects, dust and other undesirable environmental elements. These planned buffer regions have come to be known as greenbelts.

Use of small scale color and color IR photography is believed to be the most appropriate approach for planning greenbelts. With the photography on hand a study of several selected areas within HATS is possible.